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BAW 107/5
12 September 1952

PROGRAM GUIDANCE REPORT

JOINT PANEL ON THE MEDICAL ASPECTS OF ATOMIC WARFARE

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The Department of Defense
RESEARCH AND DEVELOPMENT BOARD
Washington 25, D. C.

Approved: DR. JOSEPH C. AUB
Chairman

BAW 107/5

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DETECTION, MEASUREMENT AND EVALUATION OF RADIATION

1. Military Goals

1.1 Immediate Goals

1.1.1 A device should be developed for the purpose of detecting and evaluating airborne alpha and beta hazards. This device is to measure the radiation levels of filter papers obtained through the use of standard sampling apparatus. These devices should record long lived alpha emitters in air at levels of 0.1 to 100 microcuries per cubic meter of air (log scale). The beta emitters should be recorded at levels of 1 to 1000 microcuries per cubic meter of air, an accuracy to be achieved of plus or minus 20% from 5% of full scale to full scale. The discrimination of particle size does not appear to be a feasible technical requirement for this instrument.

1.1.2 A requirement exists for the development and construction of survey type meters. These meters would serve not only to measure general environmental radiation but also as a detector for personnel contamination and may consist of the following types:

a) Alpha meter. This meter would be used in the survey of contamination of personnel, areas, filter papers, laboratory procedures, weapon duds, etc.

b) Beta and gamma meter. This would be a combined meter with a relatively high accuracy for the presence and measurement of gamma radiation, plus a window or other device which provides an indication of the qualitative presence of beta radiation, and should be provided with a shield capable of full exclusion of beta radiation. This beta radiation measurement is not required in reps, but as a representation of a relative change in the reading of total beta plus gamma as compared to gamma alone. The gamma ray ranges should extend from the order of 5 milliroentgens per hour to 500 roentgens per hour.

1.1.3 Procurement and issue of the phosphate glass personnel dosimetric devices and indoctrination in their usage is urgently needed for purposes of field testing, troop training and morale.

1.2 Future Goals

1.2.1 The continued improvement of existing equipment and techniques and correction of shortcomings determined from field tests is indicated.

2. Deficiencies of Present Equipment and Systems in Meeting Requirements

2.1 The deficiencies must be sought in field tests of detection, dosage and monitoring instruments by trained personnel, and a summarization of these observations should be referred to the Radiological Instrument Panel and other cognizant groups.

2.2 A deficiency exists in adequate evaluation of the role of cloud rise and dispersion, yield, latitude, low tropopause, and extreme meterological conditions as related to operational procedures in the determination of cloud hazard.

3. Present Research and Development Program in Support of Requirements

3.1 There are no serious problems of a technical nature.

3.2 Complete, accurate, temporal and spatial information concerning the thermal, nuclear radiation, and blast hazards of atomic bomb detonation, together with information permitting the evaluation of sublethal radiation dosages and effects in humans, will continue to furnish the only true foundation for effective personnel defense against atomic warfare, and therefore, is of unlimited military value.

3.3 The probability of successful outcome of the program is good.

3.4 No alternate programs need be considered.

3.5 No evidence of duplication of any consequence.

3.6 There are no factors seriously interfering, but better organization and dissemination of information might be accomplished.

4. Conclusions and Recommendations

4.1 Procurement, distribution and indoctrination in the use of the selected personnel dose meters and area survey meters must be given greater emphasis in order to realize a capability for effective defense.

4.2 The immediate procurements recommended in paragraph 4.1 should not prejudice the continuation of the improvement, testing, and development of the types of radiation instruments which will be needed eventually.

4.3 Definitive evaluation of the cloud hazard in terms of the cited parameters (2.2) should be accomplished with emphasis on arctic air operations.

4.4 More quantitative information should be obtained on the contamination of air by many men (such as troops) moving through contaminated areas. Since the available evidence suggests no serious hazard, this and the instrument requirement of 1.1.1 are not assigned high priorities.

PROTECTION OF PERSONNEL

1. Military Goals

1.1 Immediate Goals

Considerable data are now available on the response of critical systems of the body to radiation. The over-all defense program would be served best if the following were considered as immediate goals:

1.1.1 Organization and dissemination of information with regard to methods of attenuating radiation to innocuous levels on general external ionizing radiation, radioactive particulates, and thermal radiation.

1.1.2 In the case of external ionizing and thermal radiation, the further understanding of the use of:

(1) Barriers This would include the study of utilization of available buildings, underground structures, trenches, specially constructed barriers and fixed installations.

(2) Distance This might best be utilized by examining methods and effectiveness of dispersal of personnel.

(3) Evasive Action The possible utilization of this means would be obtained by examination of the time-intensity relationship of radiation following an atomic explosion.

(4) Partial Body Shielding This is considered in the section on therapy. It may also be useful as a protective measure.

1.1.3 In the cause of radioactive particulates, determination of the capability of presently available filter devices should be accomplished and information disseminated.

1.1.4 In the case of thermal radiation additional information on the protective effect of fabric and better organization and dissemination of information already available should be accomplished.

1.2 Future Goals

1.2.1 The future goals are testing for RW effectiveness, new types of filters and gas absorbers as developed for biological and chemical warfare.

1.2.2 Insuring that new types of protective clothing and equipment give maximum protection against RW and thermal radiation.

1.2.3 Development of prophylactic medication for individuals potentially exposed to radiation (AW-6).

1.2.4 Continuous revision of organized data and emphasis on dissemination.

2. Deficiencies of Present Equipment and Systems in Meeting Requirements

2.1 In the case of thermal radiation, considerable information is now available on time-intensity relationships, the physical factor of burning and the spectral distribution. Additional data are needed in all the aspects to provide a more nearly complete understanding, particularly for new types of weapons.

3. Present Research and Development Program in Support of Requirements

3.1 There are no obstacles to organization and dissemination of information.

3.2 No difficulties with regard to collection, organization and dissemination of information.

3.3 Alternative programs concern themselves with pharmacologic and physiologic means of protecting against radiation. Of doubtful present value.

3.4 No duplication nor gaps are evident.

3.5 There are no factors interfering with the conduct of this program.

4. Conclusions and Recommendations

4.1 Recommendations

4.1.1 The primary problem of organization and dissemination of information, together with continuous review of present manuals, still exists.

4.1.2 Additional manuals together with review and modification of existing ones on the subject of personnel protection against AW and RW are desirable.

4.2 Justifiable duplication may occur, primarily in the development of the best treatment for thermal burns and ionizing radiation injury (AW-6).

DECONTAMINATION

1. Military Goals

Research and development directed toward obtaining new and/or improved methods for decontaminating military personnel and equipment from contaminants produced during an atomic explosion or produced through the use of RW agents.

1.1 Immediate Military Goals

It is important that effort be directed toward obtaining rapid methods for decontaminating personnel and materials from radioactive substances in all environments of present or future operational significance.

1.1.1 Techniques of decontamination in extreme environmental situations, as in arctic, sub-arctic, other cold weather areas, tropic, desert and humid localities.

1.1.2 The more accurate determination of maximum permissible levels of exposure, continuous or intermittent, to contamination under field conditions. (AW-6)

1.2 Future Military Goals

In addition to continuing the efforts under paragraph 1.1 future military goals will include the following:

1.2.1 Methods for rapidly reducing internal contamination by effective pharmacologic agents. (AW-6)

1.2.2 Establishing standards of permissible contamination levels for man, i.e., the time-intensity relationships for continuous or intermittent exposure. (AW-6)

1.2.3 Continued search for new types of easily decontaminable protective coatings and strippings.

1.2.4 Testing and evaluation of decontamination techniques, materials and equipment.

2. Deficiencies of Present Equipment and Systems in Meeting Requirements

2.1 Lack of decontamination information in extreme environmental conditions such as in the arctic or tropic areas.

2.2 Lack of information relating injuries to radiation levels, including repeated radiation exposures.

3. Present Research and Development Program in Support of Requirements

The present program in the field of decontamination is insufficient with respect to extreme environmental conditions. The program should include such studies.

4. Conclusions and Recommendations

4.1 Progress in the development of new techniques of decontamination is dependent upon progress made in other fields of atomic energy, including radiation protection, dosimetry and monitoring. Decontamination problems cannot be separated from these related studies. more information is needed for successful large scale decontamination operations.

4.1.1 It is recommended that efforts be directed toward the solution of decontamination problems in the arctic, tropic, and other extreme environmental conditions using available facilities.

4.1.2 It is considered essential that rapid techniques be developed for the economical field decontamination of personnel, including burn and wound casualties, food, water and equipment.

4.1.3 Continuing research efforts should be directed toward developing new decontaminating agents, equipment, and protective coatings.

4.1.4 Obtain maximum permissible levels of exposure in man to continuous or intermittent contamination.

4.1.5 It is desirable to compile and collate continually data regarding decontamination and related areas for incorporation into operational manuals.

4.1.6 There is need for exchange of information and coordination of activities among all governmental agencies concerned with research and development in the field of decontamination.

BLAST

1. Military Goals

1.1 Immediate Goals

1.1.1 With the reality of much higher KT equivalent weapons and their probable adaptability to deep underwater detonations, it is considered important to pursue primary blast studies and to evaluate thoroughly the possible effects of direct blast injuries to personnel from overpressures in both air and underwater environments. The critical pressures required to produce these injuries under varying conditions have not been accurately determined for the blast wave forms incident to atomic detonations.

1.1.2 To determine the extent of displacement of personnel by the blast wave. This information should be provided as a function of distance and of yield, and should include information on acceleration as well as distance displaced. As a first approximation this information can be obtained from existing physical data available at the Los Alamos Scientific Laboratory.

1.2 Future Goals

1.2.1 When overpressures necessary to produce pathologic changes have been established, it will then be feasible to determine whether these critical pressures can exist under any environmental conditions without concomitant incapacitating secondary blast, thermal, or radiation injuries.

1.2.2 If this situation is found to exist, an assessment of protective measures against it must then be made.

1.2.3 Since pressure waves similar in time and intensity characteristics to those incident to an atomic explosion are difficult to duplicate in the laboratory, an evaluation of this primary blast problem is greatly desired under field test conditions.

2. Deficiencies of Present Equipment and Systems in Meeting Requirements

2.1 Since it has been found, however, that the practical difficulties

encountered under field conditions in disassocating primary blast from concomitant injuries from other sources, it is necessary to pursue parallel investigations in blast chambers in the laboratory. These studies should be done utilizing test animals with a thoracic cage and abdominal wall approximating as closely as possible those of man.

2.2 Unexpected problems have been encountered in the construction of experimental blast chambers that have delayed the laboratory approach to the problem.

2.2.1 Several types of animal holding devices have been evaluated under field test conditions which have been designed to give the desired information. Although none of these systems have proven to be entirely satisfactory, an adaptation of the Greenhouse type animal exposure chamber has indicated the most feasible approach to the problem.

3. Present Research and Development Program in Support of Requirements

3.1 The goals are technically attainable. An experimental blast tube capable of studying the primary blast effects on animals comparable in size to rats and mice will be in operation by the end of this calendar year. A blast tube capable of studying the effects on animals comparable in size to rabbits and dogs will be in operation during the first part of the next calendar year. The effects on animals comparable in size to mice and dogs will also be evaluated under field test conditions. Definite answers are expected.

3.2 Similar studies of underwater blast effects should be well under way by the end of the next calendar year.

3.3 Excellent progress in both laboratory and field studies is anticipated at moderate cost. The inclusion of underwater blast effects in the program indicates that the problems will not be completely solved for approximately two to three years.

3.4 Adequate facilities and personnel are available.

4. Conclusions and Recommendations

4.1 Further studies including both field and laboratory tests are indicated in evaluating the effects of direct blast damage to personnel. These must include an evaluation of the anti-personnel effects of overpressures accompanying both underwater and air detonations.

4.2 No unjustifiable duplication exists.

BURNS

1. Military Goals

1.1 Immediate Goals

1.1.1 To develop and evaluate simplified techniques in the first aid, treatment and handling of mass numbers of burn casualties resulting from an atomic explosion, including those complicated by ionizing radiation or other injury.

1.1.2 To develop improved techniques for simulating thermal radiation injuries for experimental study in the laboratory with emphasis on large area burns and their systemic effects.

1.1.3 To evaluate treatment and protective methods for the burn casualty; this to include (a) dextran for the prevention and treatment of shock in the burn patient, (b) proteolytic enzymes for the rapid removal of slough from third degree burns, (c) Universal Protective dressings, and (d) military fabrics to protect against thermal radiation.

1.2 Future Goals

1.2.1 To determine the mechanisms involved in the metabolic abnormalities and death in severe thermal radiation burns so as to develop more adequate methods of combatting these effects.

1.2.2 To develop methods for treating thermal injuries of the respiratory tract.

2. Deficiencies of Present Equipment and Methods in Meeting Requirements

2.1 No practical procedure has been evaluated for the handling and treating of massive numbers of burn casualties.

2.2 Techniques are essential which accurately simulate the thermal injuries of an atomic explosion, for the production of larger area burns. Such methods are urgently needed to facilitate realistic experimental studies.

2.3 No adequate method exists for the treatment of thermal injuries of the respiratory tract.

2.4 Knowledge of the exact causes of systemic injuries and death is lacking. This lack seriously handicaps the saving of life from severe thermal burns.

2.5 There is lack of knowledge of the effects of combined injuries of burns with radiation and with traumatic injury.

3. Present Research and Development Program in Support of Requirements

3.1 There has been overemphasis on the local changes involved in small area burns and insufficient emphasis on metabolic changes which result from more extensive burns. Simplification of methods for dealing with large numbers of burn casualties needs greater emphasis as also do the studies on combination of thermal radiation burns with ionizing radiation and traumatic injuries.

3.2 Reasonable accomplishment of this program should result in an increased saving of life and a decrease in morbidity and disability from burn casualties together with decreased mortality and improved rehabilitation of the seriously burned patient. Shortened periods of hospitalization and better functional results for the majority of burn cases are within sight and can be attained at a cost which is low in comparison with the anticipated economic gains.

3.3 Of especial importance in the presently proposed program are the following studies which need special emphasis:

a) The metabolic and endocrine studies including: 1) lipid metabolism of the burn patient; 2) nitrogen metabolism together with identification of the "unknown nitrogen fraction"; 3) endocrine imbalances and the interrelationship caused by stress reaction to burns; 4) the mechanisms involved in anemia and the other blood changes which follow burns.

b) Nutritional support of the burn patient.

c) Development of simplified methods for treating the moderately burned patient which can be applied by nonprofessional personnel or by the patient himself, thus freeing the medical personnel to care for the severely burned patient. It is anticipated that there will not be sufficient medical personnel to deal with the problem of mass casualties.

2.3 No alternative program is feasible.

4. Conclusions and Recommendations

4.1 Recommendations

4.1.1 The following evaluations should be concluded in 1953:

a. The Universal Protective Dressings.

b. Dextran for the prevention and treatment of burn shock.

c. Presently available proteolytic enzymes for rapid removal of slough from third degree burns.

4.1.2 Much of the effort on small area burns should be transferred from the histological to histochemical and biochemical factors and extended to large areas.

4.1.3 The study of large area burn wounds should be continued with special emphasis on a) control of infection, b) removal of slough, c) better rehabilitation of the severely burned hands, and d) prevention of scarring and contractures, especially on the face.

4.1.4 Increased emphasis should be on studies of metabolic and endocrine changes involved in severe burns so as to establish the mechanisms of systemic injuries and death.

4.1.5 Efforts to simplify the mass first aid and treatment of burns of moderate severity should be greatly increased.

4.1.6 Thermal burns continue to be a major problem and it is recommended that the program as outlined for FY 1953 and 1954, with the modifications indicated, be continued.

4.2 No unjustifiable duplication exists. In view of the urgent need for further information on the burned, burned-irradiated, and burned-traumatized casualty, duplication is desirable at this time.

BIOLOGICAL EFFECTS OF RADIATION

1. Military Goals

1.1 Immediate goals

The immediate goals are to obtain new and meaningful information on the biological effects of ionizing radiation concerning:

1.1.1 Maximum single and repeated doses of radiation which may be tolerated by man with reasonable safety.

1.1.2 Hazardous doses which may cause incapacity for performance of diverse military missions with or without permanent damage or death. Determine critical dose to incapacitate within a matter of hours.

1.1.3 Casualty-producing doses which should lead to evacuation from contaminated areas whenever possible.

1.1.4 Toxicology of radioactive materials.

1.1.5 Effects on man of moderate doses.

1.1.6 The effects of radiation as modified by various concurrent factors such as burns, trauma, infections, on environments.

1.1.7 Effects of radiation on the central nervous system and its function in man and mammals.

1.2 Future Goals

The future goal is to understand the biologic mechanisms underlying radiation damage so that potential radiation injury may be prevented, minimized or treated.

2. Deficiencies of Present Equipments and Systems in Meeting Requirements

2.1 Lack of accurate information concerning effects of various dose levels of external radiation on man.

2.2 Lack of accurate information concerning toxicology of absorbed radioactive materials.

2.3 There is lack of existing knowledge concerning the combined effects or radiation, thermal, and traumatic injury. (c.f. Burns 2.5)

3. Present Research and Development Program in Support of Requirements

3.1 The attainment of immediate goals is technically feasible provided that effects of moderate dose levels of external radiation may be observed on human patients and volunteers.

3.2 The obtaining and dissemination of necessary information is a military necessity.

3.3 Most of the immediate goals can be achieved in five years provided there is adequate financial and scientific stimulus.

3.4 Alternative programs - none.

3.5 Some duplication is inevitable and desirable in the present state of progress. The most serious gap is failure to secure adequate quantitative data on the effects of ionizing radiation on man.

3.6 The program shows no evidence of suffering from lack of planning personnel, facilities or money.

4. Conclusions and Recommendations

4.1 Researches in biological effects of radiation should be continued.

4.1.1 Continue the study of the deterioration of motor and sensory functions attending sublethal and lethal irradiation in mammals.

4.1.2 Decrease the emphasis on primates (monkeys).

4.1.3 Increase the emphasis on the mutual influence of radiation injury combined with thermal and with traumatic injury.

4.2 It is still necessary to initiate measurements of the effects of moderate doses of radiation im man.

4.3 Advantage should be taken of any opportunities for the study of the biological effects of radiation particularly in man.

4.4 Some duplication of effort in all phases of the program is justifiable and necessary for rapid progress. This refers both to duplication (a) within the Services, and (b) between the Services and the world of science.

TREATMENT OF RADIATION INJURY

1. Military Goals

   1.1 Immediate goals

      1.1.1 Intensified research for a biological factor which promotes recovery from radiation injury.

      1.1.2 Development of practical methods of segregating casualties into serious and non-serious groups and possibly into other categories, with special reference to concurrent factors such as burns, trauma and infection.

   1.2 Ultimate goals

      1.2.1 Development of more effective methods of therapy.

2. Deficiencies of Present Equipment and Systems in Meeting Requirements

   2.1 Lack of effective methods of treatment and early classification of casualties.

3. Present Research and Development in Support of Requirements

   3.1 Development of adequate therapy depends upon understanding the basic physiological changes as they affect survival.

   3.2 Military value - enormous.

   3.3 Probability of successful outcome - possibility of success.

   3.4 There is no alternative program but see succeeding section on prophylactic measures.

   3.5 Considerable duplication exists, particularly in the study of available antibiotics. Too little work is being done in the field of development of new drugs, immune bodies, and antibiotics effective against normally nonpathogenic intestinal micro-organisms, including anaerobes and possibly even fungi and protozoa, in relation to radiation injury.

   3.6 No interfering factors are evident.

4. Conclusions and Recommendations

4.1 Additional emphasis should be placed upon development of new methods and decreased emphasis on the evaluation of present therapeutic methods, such as blood and presently available antibiotics, in uncomplicated radiation injury.

4.2 No unjustifiable duplication exists.

DEVELOPMENT OF METHODS FOR PROTECTING PERSONNEL AGAINST RADIOACTIVITY

1. Military goals

1.1 Immediate goals

The testing of present methods of protecting personnel against radiation damage and the development of new methods.

1.2 Future goals

The increase to a maximum extent of man's ability to withstand ionizing radiation.

2. Deficiencies of Present Equipment and Systems in Meeting Requirements

2.1 Testing on man of methods now showing promise.

3. Present Research and Development Program in Support of Requirements

3.1 Present research, especially that on partial body shielding and possibly that on drugs, indicates that an increase in man's ability to withstand acute exposure to ionizing radiation appears possible.

3.2 Such development would be of considerable military value physiologically as well as psychologically.

3.3 Outcome of future research and development in this field is uncertain, but the rewards of success are so great the work must not be neglected.

3.4 There is no alternate program.

3.5 Considerable duplication within and outside military services now exists and is desirable.

3.6 Work is proceeding at proper level and is being pursued as fast as new scientific leads develop.

4. Conclusions and Recommendations

4.1 Consistent with the great difficulties inherent in the problem, progress is satisfactory.

4.2 No unjustifiable duplication exists.

RECOMMENDATIONS FOR RESEARCH AND DEVELOPMENT EMPHASIS

TECHNICAL OBJECTIVE AND ITEM		EMPHASIS
AW-5	Continued correlation and verification of measurements of thermal and nuclear radiations as new weapons and weapon systems are developed.	Maintain
AW-5a	Procurement and distribution of accepted personnel dosimeters and portable survey instruments together with suitable indoctrination should be accomplished.	Increase
	Hazards of flying through an atomic cloud. Assumptions and theoretical calculations require verification in terms of multiple parameters of this problem, including time variables, thermal and gamma radiation hazards, and evaluation of operational procedures under extreme meterological conditions.	Increase
AW-5c	Development and evaluation of decontamination procedures in extreme environmental conditions (arctic, tropic and desert).	Initiate
AW-6	Evaluation of present therapy of uncomplicated radiation injury (Transfusions, antibiotics, plasma, fluids, etc.)	Decrease
	Determination of hazard of ingestion and inhalation of radioactive materials.	Decrease
	Determination of single, repeated, and protracted dosages of radiation in relation to military effectiveness.	Increase Markedly
	Determination of critical dose to incapacitate within a matter of hours.	Increase Markedly
	Search for a biological factor which promotes recovery from radiation injury.	Maintain
	Evaluation of Universal Protective Dressings, Dextran for burn shock and proteolytic enzymes presently proposed for rapid slough removal.	Conclude in 1953

TECHNICAL OBJECTIVE AND ITEM (CONTINUED)	EMPHASIS
Studies of small area local burns in human volunteers.	Maintain
Studies of large area burn wounds	Maintain
Mechanism of systemic effects and death from burns.	Increase
Studies of combined effects of Thermal Burns with radiation trauma and infection.	Increase
Simplify methods for handling and treatment of mass burn casualties.	Greatly Increase

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AND
COMMITTEE ON ATOMIC ENERGY
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BAW 3/7

JOINT PANEL ON MEDICAL ASPECTS OF ATOMIC WARFARE

Minutes of Seventh Meeting
Held on 25-26 January 1951
The University of Rochester School of Medicine
Rochester, New York

MEMBERS AND DEPUTIES PRESENT:

Dr. Joseph C. Aub, Chairman
Dr. Franklin C. McLean
Dr. Rooley D. Evans
Dr. Robert R. Newell
Dr. Louis H. Hempelmann
Brig.Gen. Elbert DeCoursey, USA
Lt. Col. Frank L. Bauer, MC, USA
Maj. Gerald M. McDonnel, MC, USA
Capt. C. F. Behrens, MC, USN
Capt. V. C. Tipton, MC, USN
Dr. Sidney R. Galler, ONR
Dr. M. C. Fishler, NRDL
Lt. Col. John M. Talbot, USAF (MC)
Col. Robert H. Blount, USAF (MC)

ASSOCIATE MEMBERS PRESENT:

Mr. Allen M. Pond, USPHS
Lt. Col. Wm. J. Brown, MC, USA, Log.Div., GS USA
Dr. H. E. Pearse, Panel on Thermal Radiation, AFSWP

SECRETARIAT:

Dr. Joseph M. Pisani
Dr. Thomas B. Spencer
Dr. Harry C. Ehrmantraut
Lt. Col. Hal Bridges, MC, USA
Cdr. Joseph P. Pollard, MC, USN
Lt. Col. Charles E. Melcher, USAF (MC)

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OTHERS:

Dr. Wallace O. Fenn, Comte on Medical Sciences
Dr. Paul Beall, RDB
Mr. David Z. Beckler, Comte on Atomic Energy
Mr. F. H. Quimby, ONR
Dr. L. W. Tuttle, AEC

1. Minutes of the Sixth Meeting.

After a discussion of the implementation of the Minutes, including recommendations of the group concerning the catastrophe team project now being formulated,

The Panel:

Approved the Minutes of the Sixth Meeting.

2. Technical Estimates, 1951.

After reviewing the pertinent documents,

The Panel:

Prepared its Technical Estimates for 1951, BAW 13/4, Log No. 38684, appended hereto as Attachment A.

3. Resume Reports on Research Progress in Technical Areas.

A. Dr. McLean reported on the handling of catastrophes in the discussion of the catastrophe team project.

B. Lt. Col. Talbot reported on problems important to aviation.

C. Other reports were deferred until a future meeting.

4. Effects of Ionizing Radiation on Primates.

In the absence of Dr. Andrews, Mr. Pond reported on the status of this project for the Panel's information. The Minutes of the meeting of an Ad Hoc Panel (NIH) which considered this project and made pertinent recommendations to the National Advisory Cancer Committee

are appended as Attachment 3 for Panel members only. No action has been taken on these recommendations, and they are appended only for informational purposes.

5. Human Experimentation.

General James P. Cooney was unable to attend the Panel meeting but indicated that the following should be entered into the Minutes of the meeting:

At a meeting of the Advisory Group to the Division of Biology and Medicine of the Atomic Energy Commission which occurred shortly after the Sixth Panel Meeting (31 Oct-1 Nov 1950), the three Services were represented by Admiral Greaves, General Powell and General Cooney, who were queried concerning any problems that they might have for the Advisory Panel to consider. General Cooney addressed Dr. Alan Gregg, the Chairman of the Advisory Committee by indicating that the military had a definite problem because of the fact that the atomic bomb might possibly be used as a tactical weapon. Under such conditions it is reasonable to assume that a large force might be subjected to aerial bombardment and a relatively short time later the commanding officer would confront his Medical Officer with the following: "I have 'X' thousands of men who have been subjected to various amounts of ionizing radiation from 25 to 150 r or more. How many men can I take into battle? How many will be sick? When will they be sick? How many replacements shall I request and when shall I ask for them?" Up to the present time the military has expressed opinions concerning answers to the above but there has been no official backing by any

authoritative medical group. Many individuals feel that we have sufficient data on humans to give these answers. Others feel we do not and therefore some human experimentation should be done on military volunteers to whom the effects of ionizing radiation have been explained in detail.

Military medicine has the responsibility of maintaining high medical standards which the American Medical Association and other allied groups insist upon. If American medicine were satisfied with the data on the effect of ionizing radiation on humans, then military medicine would also be satisfied. If such information is not available, then it was requested that procedures be outlined to obtain same.

The Advisory Panel then had a long discussion on the problem of human experimentation and it was the consensus of this group that human experimentation was probably not the answer at this time due to the fact that in order to obtain statistically significant results several thousand people would have to be exposed to ionizing radiation. Dr. Shields Warren expressed his opinion that sufficient data was already at hand. Dr. Gregg then asked the representatives of the Services whether or not they would like to have him convene a panel of men who have had a large amount of experience in this field as members. The representatives from the Services welcomed this suggestion and as a result a meeting was held on 6 December 1950 in Washington.

(The results of this meeting are contained in the letter, appended as Attachment C, BAW 10/3, which was distributed at the Panel. The subject letter was addressed to Mr. Robert LeBaron, Chairman of the Military Liaison Committee by Mr. Boyer of the Atomic Energy Commission. The Military Liaison Committee disseminated this letter to the Chief of Staff of the Army, the Chief of Staff of the Air Force and the Chief of Naval Operations, who in turn have disseminated this information widely to the individual Services.)

These opinions, since they are based upon impressions rather than experimental data, do not negate the necessity for human experimentation at some future date. It is felt, however, that the acute need for this human experimentation has been somewhat relieved and therefore diligent efforts for the establishment of this program may be temporarily curtailed. Implications and impression never replace facts.

6. Report on Ventilation Systems of Airplanes.

Radiation Hazards in Air Force Operations

In connection with the question of fission product contamination of the cabin atmosphere and surfaces of aircraft flying through a radioactively contaminated atmosphere, calculations suggest that the inhalation hazard for crew members in anticipated AW situations is negligible but that the likelihood of extremely serious external gamma ray exposures is a real one. Col. Blount requested the Panel opinion on the need for filtering cabin pressurizing and ventilating

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JOINT PANEL ON MEDICAL ASPECTS OF ATOMIC WARFARE
TECHNICAL ESTIMATES, 1951

The Joint Panel on Medical Aspects of Atomic Warfare submits the following technical estimates pertaining to its interest in AW-5 and AW-6:

1. Biological Effects of Radiation. Of the many effects of radiation upon biological systems the chief concern of this Panel is with the dosages of external radiation (chiefly gamma rays) and of internal radiation (chiefly alpha and beta emitters) which are of immediate military significance in that they will reduce the effectiveness of troops, produce casualties, or compel the evacuation of occupied areas. Long term effects, such as reduction in fertility, increase in the number of mutations, and reduction in the ultimate life span of exposed individuals, will be the concern of military planners, but will hardly affect the decisions of commanders in the field.

External gamma radiation. Tentative figures for doses of total body gamma radiation, acceptable as military risks, have been adopted by competent authority, and these figures are available for the guidance of planners and commanders until they are corrected on the basis of experience. Such experience can be gained by observation of human volunteers, or under actual combat conditions. Further light may also be thrown on the subject by additional animal experimentation, such as the exposures of large animals planned at Oak Ridge, and the observations on primates now proposed under the joint auspices of the National Institutes of Health and the Atomic Energy Commission. Some revision of the tentative figures may be possible by 1953. In the meantime, the influence of other factors, such as time-intensity, depth-dose, and concurrent injury (burns, etc.) upon the effects of external radiation, is under study by means of animal experimentation.

 Attachment A to BAW 3/7

SECRET

Internal Radiation. (Chiefly inhalation of alpha and beta emitters). The assessment of the hazard from possible inhalation of radioactive material is complicated by the time of burst, the variety of materials, their solubilities and their local and systemic deposition and effects after inhalation. Further developments in instrumentation are also required to assess the hazard under any given conditions.

At the present rate of progress, a reasonably satisfactory understanding of the many variables involved in the hazards from inhalation of alpha and beta emitters should be available by 1956.

2. Therapy of Radiation Injury. The therapy of radiation injury is under intensive investigation in animals and present methods of treatment should be thoroughly tested by 1953 (1954). The use of antibiotics as an adjunct to general supportive therapy is still the most promising of the methods now under study. The use of antibiotics together with the improved facilities for patient care and administration of supportive therapy should decrease the number of deaths by 50%. Long range technical estimates on improvement in the treatment of radiation injuries will depend entirely upon future discoveries in the field of radiation biology and associated sciences.

3. Protection of Personnel. Protection against hazards of radiation may be obtained by various means including evasive action, whole and partial body shielding, decontamination, and the use of substances which are under investigation. At the present rate of progress in the discovery and evaluation of protective substances and technics, there will be a choice of methods by 1954 which will reduce mortalities by 50%. The means of collective and individual protection against radioactive particulates are now available. Efficient filters and masks have been developed and knowledge is adequate concerning skin protection. The successful use of these means is largely dependent upon indoctrination and discipline.

4. Thermal Burns. The problem of thermal burns in atomic warfare, from the practical standpoint of care of casualties, is by far the most important. In spite of the enormous research effort in this field, there is little prospect of markedly reducing this hazard in atomic explosions or of protecting against it beyond our present state of knowledge. It is expected that the use of protective clothing will be evaluated by 1952. In the treatment of thermal burn casualties, it is expected that between 1954–1956 (1955–1958) significant reduction (50%) in fatalities will be achieved by means of development of procedures, selection and stockpiling of essential medical materiel, and development of fundamental knowledge for indoctrination of personnel.

5. Blast. The hazards of blast effects in atomic weapons will be assessed by 1953 (1952). This is because of unavoidable difficulties and consequent delays in the construction of the blast generator.

From the current and contemplated level of effort, better understanding of atomic blast injuries and a more accurate approach to

the general problem of blast casualties are expected. However, improvements in hazard reduction, protective measures and therapy are in the main unlikely or conjectural.

6. Decontamination of Food and Medicinals. Essential information for the decontamination of certain types of packaged foods and medicinals (as in undamaged metal waterproof containers) under some environmental conditions is now generally available but not completely evaluated. However, a choice of techniques will probably be available for application and/or refinement by 1952. Knowledge about the decontamination of animal and vegetable crops raised in contaminated land and/or water areas is not well evaluated and will not be available for application before 1954.

7. Decontamination of Water Supplies. Information necessary for the decontamination of domestic and industrial water supplies is 50% available but not completely evaluated. A choice of techniques and equipment will be ready for large scale application in 1953.

Information about permissible dosages needed for producing potable water under emergency field conditions from sources contaminated with short-lived radioactive materials is available for immediate use. Therefore, the beta-gamma tolerance values are most useful during periods not exceeding a month after a nuclear explosion. Permissible dosage information for the production of potable water under emergency field conditions from sources containing long-lived radioactive contaminants will be available by 1952.

8. Personnel and Equipment. Basic information needed for the external decontamination of personnel and equipment under some operating conditions is being obtained at a satisfactory rate and a choice of decontamination techniques should be available by 1952.

9. Decontamination under Extreme Environmental Conditions. The problems associated with the decontamination of personnel and equipment under extreme environmental conditions (arctic, desert or other areas where water is not readily available) have not been evaluated. Effective evaluation should be accomplished in one year after such a program is initiated.

10. Decontamination of Burned and/or Wounded Personnel. Basic Information needed for the establishment of standard procedures for the decontamination of burned and/or otherwise wounded areas of the skin will be approximately 50% available by 1952 and completely available by 1953.

11. The Effects of Sublethal Dose Irradiation upon Spontaneous Activity, Motivation, Learning, and Retention of Learning, in Laboratory Animals. In rats, a good evaluation for activity and motivation will be available by 1953; for learning and retention of learning by 1954. By 1952, these investigations will have been extended to monkeys and a quantitative evaluation should be obtained by 1955.

ATOMIC ENERGY COMMISSION
Washington 25, D. C.

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BAW 10/3

January 10, 1951

Honorable Robert LeBaron
Chairman, Military Liaison Committee
P. O. Box 1814
Washington 25, D. C.

Dear Mr. LeBaron:

As you know, one of the important problems that would confront us in the event of a war in which nuclear weapons were employed would be the amount of external radiation from radioactive materials that military personnel could tolerate and still effectively carry out their assigned duties and missions in the Armed Forces. This problem was a principal subject of discussion at the November 10, 1950 meeting of the Atomic Energy Commission's Advisory Committee for Biology and Medicine. In attendance at this meeting were Rear Admiral F. C. Greaves and Captain C. F. Behrens of the Bureau of Medicine and Surgery, Brigadier General William H. Powell, Jr., of the Office of the Surgeon General, Air Force, and Brigadier General James P. Cooney, Army Medical Corps, and Chief of the Radiology Branch, Division of Military Application, Atomic Energy Commission. It was suggested at this meeting that it would be helpful to the Armed Forces to have the opinions of an ad hoc commission, composed of physicians and radiologists whose recommendations would be recognized as authoritative, to advise the Armed Services of the permissible levels of radiation to which troops could be exposed and still be expected to be effective as fighting forces.

In order to obtain an accurate and authoritative answer to the question raised at the meeting, the Division of Biology and Medicine of the Atomic Energy Commission has consulted with a group of the physicians and scientists of this country whose experience in this field has been broadest and most extensive, and whose reputation for clear thinking and good judgment renders their advice and opinions of very great value. This group includes clinicians and radiologists experienced in the use of X-ray and radium in the treatment of human patients and who have had occasion to radiate the human body in such treatments; it includes physicians and scientists who were in Japan at the close of the last war and carefully studied bomb victims at Hiroshima and Nagasaki, the physician who treated the victims of the three accidents involving acute radiation injury in the history of the Manhattan Project and the Atomic Energy Commission; scientists who have conducted and are well acquainted with the results of experiments on the effects of radiation on

various species of experimental animals, including the genetic effects of radiation; and physicians who were members of the Medical Board of Review which appraised the medical work of the Manhattan Engineering District.

On December 8 these men met as a group in Washington at the request of the Atomic Energy Commission. Attending and taking part in this meeting were:

Dr. Alan Gregg, Director of the Division of Medical Sciences Rockefeller Foundation, and Chairman of the AEC Advisory Committee for Biology and Medicine, who acted as chairman of this meeting.

Dr. Austin M. Brues, Associate Professor of Medicine, University of Chicago Medical School, and Senior Biologist and Director of the Division of Biological and Medical Research, Argonne National Laboratory of the AEC.

Dr. Simeon T. Cantril, Radiologist with the Tumor Institute of the Swedish Hospital, Seattle, Washington, Consultant to the Atomic Energy Commission and to General Electric Company in their operation at Hanford Works during the last war full time with the Manhattan Project.

Dr. Andrew H. Dowdy, Professor of Radiology and Chairman of the Department, Medical School of the University of California at Los Angeles, formerly Professor of Radiology at the University of Rochester Medical School and head of the Atomic Energy Commission research laboratories located there.

Dr. Louis H. Hempelmann, Associate Professor of Radiology at the University of Rochester Medical School, Special Assistant to the Director of the Division of Biology and Medicine of the AEC, formerly head of the Health Division, Los Alamos Scientific Laboratory.

Dr. Robert F. Loeb, Bard Professor of Medicine, College of Physicians and Surgeons, Columbia University. Specialist in Pathology and Internal Medicine, Chairman, Medical Board of Review, Atomic Energy Commission, 1947.

Dr. Curt Stern, Geneticist and Professor of Zoology, University of California, member of AEC Advisory Committee for Biology and Medicine, formerly Chairman of Division of Biological Sciences, University of Rochester, and geneticist with the AEC Atomic Energy Project located there.

Dr. Shields Warren, Professor of Pathology, Harvard University Medical School, Division of Biology and Medicine, Atomic Energy Commission.

Brigadier General James P. Cooney for the Army, Admiral Thomas C. Anderson and Dr. Robert Flynn for the National Security Resources Board, and Major Gerrit L. Hekhuis for the Air Force.

The last-mentioned group attended this meeting for the purpose of presenting to the group in further detail the problems in this field already raised by the armed forces and to obtain personally the conclusions and recommendations of this committee on the subjects of importance to the armed forces and civilian defense agencies.

Members of the Division of Biology and Medicine of the AEC acted as staff to this committee in collecting and summarizing pertinent available research data and clinical information and presenting it to the committee for their consideration.

As a supplement to information gained personally by armed force and civilian defense representatives at this meeting, the Committee has asked me to write this letter summarizing their views on the pertinent questions asked them.

This letter was submitted to each of them for any suggestions or corrections they cared to make, and I can now tell you that the members of this committee were in unanimous agreement that what follows is a correct summary of their joint conclusions.

Question 1: Assume that troops are acutely exposed to penetrating ionizing radiation (gamma rays). At what dosage level will they become ineffective as troops?

Answer of the Committee: Uniform dosage of 50r to a group of armed force personnel will not appreciably affect their efficiency as a fighting unit.

Uniform acute dosage of 100r will produce in occasional individuals nausea and vomiting, but not to an extent that will render armed force personnel at any time ineffective as fighting units. Troops receiving an acute radiation dose of 100r and above ought to be given, as soon as feasible (within a week, if possible), a period for rest and individual evaluation.

Uniform acute dosage approximately 150r or greater can be expected rapidly (in a few hours) to render armed force personnel as a group ineffective as troops through a substantial incidence of nausea, vomiting, weakness and prostration. Mortality produced by an acute dose of 150r will be very low and eventual recovery of physical fitness usually may be expected.

Field officers should therefore assume that if substantial numbers of their men receive acute radiation doses substantially above 100r, there is grave risk that their commands will rapidly become ineffective as fighting units.

Question 2: What dosage will render an air crew inefficient, that is, unable to complete a mission, during a flight of one to three hours, four to twelve hours, twelve to forty-eight hours?

Answer of the Committee: In all three cases if radiation dosage to flight crew members is held below 75r, radiation exposure will be unimportant in determining the success or failure of a mission provided the crew members had not previously recieved an appreciable amount of radiation. In all three cases radiation doses substantially above 75r, combined with human stresses associated with military aviation missions in wartime, are considered to very seriously reduce the odds for successful completion of a mission.

Question 3: How often may an aircraft crew accept an exposure of 25r per mission and still be a reasonable risk for subsequent missions?

Answer of the Committee: It is probable that at least eight missions can be carried out at weekly or longer intervals, with exposure of 25r per mission, before the chance of mission failure becomes large due either to illness during the mission or significant general deterioration in health and ability. More missions may be feasible, but personnel should be carefully checked and evaluated before each mission and particularly before a decision to permit greater exposure than 200r total in these divided doses is made.

The possibility should not be ignored that cumulative radiation doses to the entire body above 200r may substantially reduce the life expectancy of the irradiated individual.

Question 4: A submarine crew are recieving 25r per mission. How many missions should they be allowed to make?

Answer of the Committee: The answer is substantially the same as to question 3. It is probable that at least eight missions can be carried out. Personnel ought to be carefully checked and evaluated after each mission. The possibility of substantial reduction in life expectancy by radiation doses totaling over 200r should not be ignored.

As indicated earlier, in arriving at these conclusions the Committee took into account the results of extensive animal experiments, the response of patients treated for disease by X-ray and radium, observations on the effect of radiations from the atom bomb detonated over the Japanese cities of Hiroshima and Nagaski, and accidental radiation exposures within the Manhattan Project and the Atomic Energy Commission.

I believe you can accept these values as realistic appraisals that can be used in planning with the convictions that their predictions will be closely fulfilled in practice.

We are sending copies of this letter to the Chief of the Bureau of Medicine and Surgery, Department of the Navy, and the Surgeons General of the Army and Air Force.

Sincerely yours,

Marion W. Boyer
General Manager

...IC AND CLINICAL EFFECTS INDUCED IN 263 CANCER PATIENTS BY ...E-BODY X-IRRADIATION WITH NOMINAL AIR DOSES OF 15 TO 200 R

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May 1957

SYSTEMIC AND CLINICAL EFFECTS INDUCED IN 263 CANCER PATIENTS BY WHOLE-BODY X-IRRADIATION WITH NOMINAL AIR DOSES OF 15 TO 200 R

INTRODUCTION

Some effects of human whole-body irradiation are known from the following sources: first, studies of atomic bomb casualties (1); second, findings obtained from persons involved in nuclear accidents (2), and third, observations made on patients receiving therapeutic radiation (3, 4, 5). Singly these data are of limited value because either the dose is ill-defined or the subject is not a healthy human being; collectively, however, they allow reasonable conclusions that will become increasingly accurate as more observations are reported. The present study, originating from therapeutic considerations alone, attempts to contribute such additional information.

It has been established that chemotherapy, for a transitory period only, may relieve pain and cause subjective improvement in cases of incurable generalized tumors, quite frequently even those of low radiosensitivity. Because of its less severe side effects, whole-body x-irradiation has been suggested as a superior method for the palliative treatment of such patients (6). Is whole-body x-irradiation, here, an effective procedure? If so, how high is the dose that can or must be administered to obtain beneficial results?

To answer these questions, a long-term study was initiated in 1951 and continued until 1956. From the beginning it was realized that significant clinical benefit could be expected, if at all, only at a dose level bordering the clinical threshold dose or clinical tolerance dose, beyond which serious complications might occur. Paucity of knowledge about this important range necessitated cautious exploration beginning at rather low doses. In the range from 15 to 25 r, whole-body roentgen therapy commonly has been used in the management of leukemias (7), on the basis of this experience, similar small doses were applied first to other, less radiosensitive, generalized tumors. With additional experience gained from careful observation of the patients, the dose was raised in later cases in steps of 25 r. The exploratory phases of the inquiry comprised 233 patients exposed to doses ranging from 15 to 200 r; the final phase consisted of a series of 30 patients who received 200 r. The nature of this study necessitated extensive general, clinical, and laboratory surveillance of the irradiated persons to detect promptly any harmful effect induced by the treatment.

The present report describes in some detail the findings obtained in the final phase of the investigation, but only the most essential observations made during the exploratory phases. Furthermore, it emphasizes those aspects of the problem which are of general radiobiologic interest; a strictly clinicotherapeutic evaluation will be given elsewhere (8).

Received for publication on 4 Feb. 1957.

METHOD

Chronologic evolution of study and standard for case selection

During the first two years, relatively low doses (15 to 75 r) of whole-body x-irradiation were employed largely as adjuvants to limited field exposure or hormone treatment, and were administered either concomitantly with or shortly before initiation of the conventional therapeutic procedure. For this first exploratory phase, therefore, patients were selected whose disease was in such a state that cure or at least definite palliation could still be expected from established methods of treatment. These low doses were tolerated well enough to raise hope that higher doses of whole-body exposure, similar to nitrogen mustard, might prove useful as an independent form of palliative therapy.

Thus, in a second phase, such as exploration of the dose range from 15 to 200 r was started. Understandably, the greater possible risk necessitated now the selection of patients whose disease had advanced to such a state that, in general, significant benefit could not be expected from conventional procedures other than systemic ones. Therefore, in combination with whole-body exposure, additional forms of treatment were administered less frequently. Again the tolerance was such that exposure to 200 r seemed justified for a last group of 30 patients. In this final phase of the study standards for selection of cases were even more severe. All patients showed such an advanced state of disease (figs. 1 and 2) that cure by conventional means was regarded as completely hopeless. Of the 30 cases—prior to whole-body irradiation—21 had received neither radiotherapy nor chemotherapy, 3 had been subjected to either one or both of these treatments, and 1 had already received whole-body irradiation. Composition of the 200-r group varied widely with respect to age and type of malignancy (table I). At the time of irradiation these patients were still able to walk, perform light physical tasks; they knew about the advanced state of their disease and the experimental nature and possible risks of proposed radiotherapy.

FIGURE 1

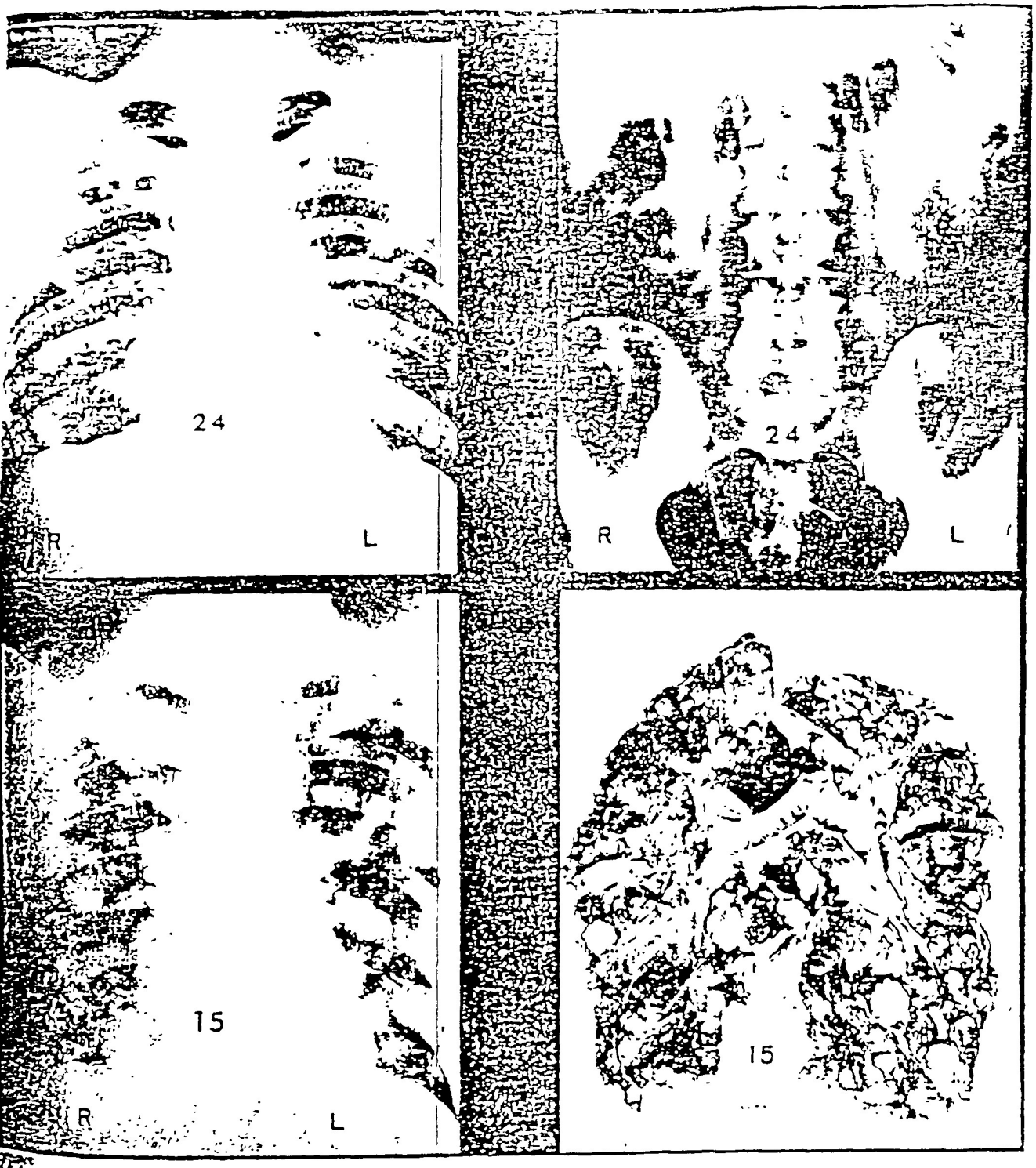
Unclassified malignancy. Numerous subcutaneous tumor masses are widely disseminated over the anterior chest wall. The photo depicts condition prior to whole-body exposure to 200 r (case 5).

General procedure

After conclusion of the first exploratory phase (15 to 75 r), a routine procedure was adopted as follows: the patients were observed for an initial 2-week period that was divided into three sections. A preradiation interval of 4 days was followed by whole-body exposure on the fifth day and by a postradiation interval of 9 days. During these 14 days, hospitalization occurred only in those cases where it was required by clinical considerations or lack of housing facilities; in the majority of cases the patients continued to live on the outside and appeared daily at the clinic for check-up or treatment. Hematologic data from the peripheral blood were obtained daily with ordinary laboratory methods. No attempt was made to standardize diet or physical activity of the patients. Following completion of the initial 2-week period, the pattern of observation varied widely. The few patients who remained hospitalized could be seen and examined daily. Of those released, the majority appeared more or less regularly for follow-up examinations, frequency of visits depending largely on distance between hospital and home town; approximately 15 percent were lost from sight.

Irradiation

A Maxitron (G.E.) operated at 250 kvp with a Thoraeus III filter, providing a 3.0 mm. copper HVL, served as x-ray source. The tube was used without a diaphragm, and the beam was aimed horizontally at a wall 240 cm. away. Sitting laterally to the beam the patient, in a slumped-over position, covered approximately one-half of the circular area outlined by the cross section of the beam (fig. 3). The distance between x-ray source and midline of the patient was 205 cm. At this distance the dose rate in air averaged 3.8 r/minute. After one-half of the exposure had been delivered—100 r based on



Composite picture

FIGURE 2

Upper left: Roentgenogram of chest taken prior to whole-body exposure. Several tumor masses are evident the left and right lung fields (case 24).

Upper right: Roentgenogram of abdomen and intravenous pyelogram taken prior to whole-body exposure. The kidney has been replaced by a large tumor mass (case 24).

Lower left: Roentgenogram of chest taken prior to whole-body irradiation. Tumor infiltrations throughout and right lung fields are visible (case 15).

Lower right: Photo of lungs after autopsy. The cancerous masses have replaced most of the normal lung tissue e 15).

air dose at midline—the patient was turned around 180 degrees and exposed to the other half dose. Total exposure, performed in a single session, required approximately 51 minutes. Detailed analysis of dosimetric problems encountered in this study, determination of dose distribution throughout the body, and estimation of integral doses have been reported separately (9).

RESULTS

On the ensuing pages the findings are arranged in sections. In the first section observations made on the final 200-r are reported in some detail since in this effects produced by irradiation could be rated to a large extent from those attributable to the disease, and since these patients

TABLE I

Survey in chronologic order of the final group of 30 patients who received single whole-body exposure to a nominal air dose of 200 r.

Case No.	Age (years)	Histologic diagnosis	Origin of tumor	Survival (months)
6	50	Adenocarcinoma	Undetermined	11.6
7	76	Adenocarcinoma	Kidney	1.0
8	78	Melanoma	Skin	1.7
9	64	Undifferentiated carcinoma	Bronchus	0.5
10	46	Melanoma	Eye	13.5
11	33	Ewing's sarcoma	Rib	7.4
12	64	Squamous carcinoma	Bronchus	1.1
13	65	Squamous carcinoma	Bronchus	1.0
14	63	Squamous carcinoma	Bronchus	8.6
15	23	Plurigeneric carcinoma	Testis	0.4
16	57	Squamous carcinoma	Tonsil	14.2
17	59	Undifferentiated carcinoma	Bronchus	1.0
18	25	Plurigeneric carcinoma	Testis	6.8
19	52	Squamous carcinoma	Bronchus	11.0
20	50	Squamous carcinoma	Bronchus	5.2
21	57	Undifferentiated carcinoma	Bronchus	0.5
22	51*	Lymphosarcoma	Undetermined	19.2
23	48	Undifferentiated carcinoma	Bronchus	3.3
24	56	None	Kidney	0.9
25	61	Undifferentiated carcinoma	Bronchus	3.4
26	43	Adenocarcinoma	Bronchus	2.6
27	75	Squamous carcinoma	Skin	1.5
28	26	Plurigeneric carcinoma	Testis	0.5
29	52	Adenocarcinoma	Colon	4.1
30	41	Adenocarcinoma	Adrenal	8.2
31	60	Adenocarcinoma	Liver	3.6
32	62	Undifferentiated carcinoma	Bronchus	3.5
33	67	Adenocarcinoma	Pancreas	1.3
34	55*	Hodgkin's disease	Undetermined	3.3
35	61*	Adenocarcinoma	Breast	0.8

*Female.

watched more closely than the others. In the second section, findings obtained from the exploratory groups are described rather cursorily, a more exhaustive treatment seems uncalled for since symptoms induced by the advancing disease frequently obscured the milder ones possibly produced by radiotherapy. In the third section, observations are presented for a few patients who received two separate doses of whole-body irradiation.

1. Final 200-r group

Early reactions to irradiation with 200 r were relatively mild in most instances. Only 2 of the 30 patients composing the final group became nonambulatory within the first postradiation week, one of these (case 18) had to be confined to bed soon after treatment and had to remain there throughout the next day because of nausea, vomiting, and weakness; the other (case 21) became bedridden owing to accentuation of a cardiac decompensation which existed before the radiotherapy. The remaining 28 patients experienced during the first 3 days posttreatment a more or less pronounced impairment as described in the next paragraph.

Nausea and vomiting. Upon interrogation, all but 3 of the 30 patients reported an impairment of condition which was described as either fatigue, decreased energy, drowsiness, or malaise, and which was accompanied by a loss of appetite. Usually, this condition developed within a few hours posttreatment and progressed to nausea or actual vomiting in most cases. Invariably, the latter symptoms then overshadowed the previous ones to such a degree that a clear separation was impossible. Among the 30 final 200 r cases irradiation was not followed by vomiting in 13, and in at least 5 of these, not even by nausea (table II). Only one of the 13 patients was receiving antinausea medication since he continued to take four times each day the 25 mg doses of chlorpromazine hydrochloride prescribed earlier by his referring physician; this fact was discovered at a later interrogation. In the majority of the remaining 17 cases nausea and actual vomiting appeared within the first few hours following exposure (table III) and subsided after the 3d postradiation day. Among these patients, 10 showed complaints of such a moderate degree that antiemetic treatment

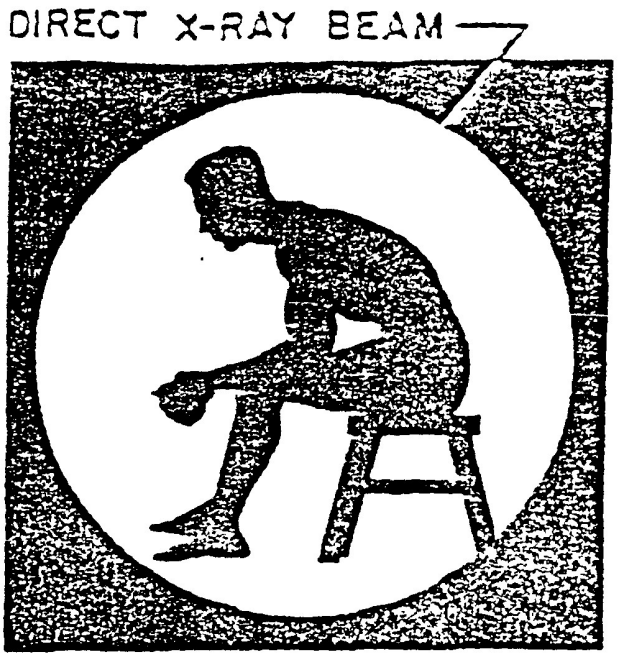


FIGURE 3

Schematic drawing of patient during exposure which shows that the entire body is well within the central homogeneous area of the direct beam and that no body part enters the fringe zone where x-ray intensity diminishes.

TABLE II

Incidence of vomiting and nausea induced in 30 patients within 72 hours following whole-body irradiation with 200 r.

Did vomit	
Antiemetic and venoclysis required	2
Antiemetic alone required*	5
Antiemetic not required	10
	17
Did not vomit	
Nausea absent	6
Nausea present	5
Not recorded	2
	13

*In all but one of these cases antiemetic therapy was required during the preradiation period also.

was not indicated; 5 required chlorpromazine hydrochloride, usually in oral doses of 25 mg. every 6 hours; and 3 exhibited reactions sufficiently severe to necessitate both antiemetic medication and parenteral fluid replacement. In all cases these measures yielded prompt improvement. It must be emphasized that it was impossible to analyze to what extent nausea and vomiting, not infrequently occurring spontaneously in such a group of patients, were caused by irradiation alone, or by the combination of radiotherapy and disease.

As revealed by numerous animal experiments the body weight must be considered a rather sensitive indicator of radiation-induced impairment of nutrition. Therefore, daily weight measurements were performed until the 9th day postradiation on 11 of the 200-r patients. During this time no appreciable change in mean body weight of the group occurred, statistical evaluation of the data showed no significant trend. Among the group only one patient, case 18, developed appreciable weight loss (7 pounds) within the first 24 hours after radiotherapy; this obviously was caused by profuse vomiting and normal weight was restored by the 4th postradiation day.

Thus it must be concluded that anorexia, nausea, and vomiting only occasionally reached such a degree as to compromise satisfactory nutrition of the patients.

Body temperature and blood pressure, recorded systematically in some of the cases only, revealed no significant change. However, the value of these observations must be considered as rather limited since the activity of the patients was not controlled.

To illustrate the points discussed so far, excerpts are taken from the histories of 2

TABLE III

Distribution of vomiting during first 72 hours following whole-body irradiation with 200 r.

Case No.	First emesis (hours post-irradiation)	Frequency of emesis		
		First 24 hours	Second 24 hours	Third 24 hours
6	1	4	4	3**
7*	Not recorded	2**	0	0
9	58	0	0	3
13	3¼	9	12	4**
15	1	1	0	0
16	28	0	4	0
17*	Not recorded	1**	1**	1**
18	2	5	2**	0**
19	60	0	0	1
21	2¼	2	0	0
22	2	1	0	0
24	30	0	1	0
28*	Immediate	4**	0**	0**
31	4	1	0	0
32	1	3	0	0
34*	Not recorded	7**	4**	0**
35	60	0	0	1

*Administration of chlorpromazine hydrochloride during preradiation period.
**Treated with chlorpromazine hydrochloride.

patients, showing the mildest and the severest initial reactions, respectively. *Case 11*, a 33-year-old minister, had Ewing's sarcoma originating from the posterior segment of the right 4th rib. Resection and two subsequent courses of local roentgen therapy had failed to prevent recurrence. On 14 December 1954 he received 200 r whole-body x-irradiation; the exposure was started at 6 o'clock in the morning. After completion of the treatment, examination, and laboratory studies, the patient left the hospital at noon. He had a meal and subsequently a one-hour rest as was his custom, then worked at ministerial duties until 9 o'clock in the evening. On each of the succeeding days he devoted at least 10 hours to his professional obligations. Upon interrogation, he admitted having had a few episodes of "minimal nausea" during the first 2 days after treatment, but anorexia, vomiting, or other complaints were denied. *Case 18*, a 25-year-old male, had mixed testicular embryonal carcinoma and seminoma with bilateral pulmonary metastases. Since two trials of local roentgen therapy had produced only temporary improvement, he received 200 r whole-body x-irradiation on 18 April 1955. The treatment was completed at 7:30 a.m. Approximately 2 hours later severe nausea, vomiting, and prostration developed. During the first 24 hours following exposure he vomited 5 times and lost 7 pounds in body weight. Most of the vomiting occurred within the first 8 hours, and he was able to eat and retain supper that night and breakfast next morning. Extreme weakness—necessitating stretcher transport—and moderate nausea persisted however throughout the first postirradiation day. On the following day, therefore, he received intravenously 1 liter of normal saline solution with 10 percent dextrose, and was started on 25 mg. doses of chlorpromazine hydrochloride, four times each day. Thereafter recovery was rapid. On the second postradiation day he vomited only twice and regained 4 pounds of his lost weight. No further parenteral fluid supply was required. Ambulation was resumed on the third postradiation day. On the fourth day, his body weight had returned to normal level, and chlorpromazine medication was discontinued.

Effect on the disease. After the third postirradiation day the initial reactions—essentially fatigue, anorexia, nausea, and vomiting—had subsided, and the general condition of most of the patients had returned to the preradiation level. Shortly thereafter approximately 30 percent of the group claimed subjective improvement at least temporarily; frequently, however, these claims could not be supported by objective findings. In most cases psychologic rather than clinical factors might have been responsible for the alleged transitory improvement, and in only three instances could a somewhat more concrete effect be established. *Case 11* stated that within 4 days after exposure his pain vanished for the first time in 4 months; for 10 days he did not use analgesics and narcotics necessary prior to radiotherapy; following this transitory improvement, however, he relapsed to his preradiation condition. *Case 33*, previously experiencing severe right shoulder and arm pain believed due to large metastatic masses in the right supraclavicular fossa and right axilla, claimed marked, although incomplete, relief developing on the third postradiation day. This relief coincided with a questionable slight decrease in size of the tumor masses; pain returned 2 weeks later when the tumor began to advance again. *Case 22*, a negress, suffered from generalized lymphosarcoma. Following irradiation she reported a gain in general strength, substantiated by an increase in body weight and by a slow but definite shrinkage of the tumor masses in rectal mucosa and nasopharynx. About 2 months later she was able to resume work as housewife, farm helper, and practical nurse. Further treatment was not required. This improved state persisted until approximately 2 weeks prior to her death that occurred one year and 7 months postirradiation.

In summary, 200 r whole-body x-irradiation produced a definite transitory amelioration of the disease in 3 cases, and a questionable improvement in several additional patients.

Hematology. The hematologic data obtained during the 2-week initial observation period showed definite radiation-induced changes (table IV). For statistical evaluation the group means of the measurements on each postradiation day were compared with the corresponding values determined 2 days prior to exposure, and Student's t-test was applied to the differences. This procedure yielded the following result: significance on the 0.01

level was reached for the total white cell count, on the 7th postradiation day; for the lymphocyte count, on the 2d postradiation day; and for the platelet count, not at all. Hence it may be concluded that, with a probability greater than 99 percent, the drops in leukocyte and lymphocyte counts were not the result of chance alone. Red cell count, hemoglobin, and reticulocyte count (not tabulated) did not show significant changes. Results of iron-59 clearance and uptake studies were treated in a separate report (10).

In 4 cases long-term observations could be performed regularly enough to allow graphic representation (figs. 4-9). The total white count (fig. 4) reached a minimum between the 4th and 6th postradiation weeks—the sudden rises in cases 33 and 27 must be regarded as terminal phenomena; the lymphocyte count (fig. 5), exhibiting the earliest and most pronounced drop, showed little indication of recovery; and the platelets (fig. 6) essentially paralle[led] the white count except for absence of [ter]minal rises. Red cell count (fig. 7), he[mo]globin (fig. 8), and hematocrit (not represente[d]) displayed a tendency toward a gradual declin[e] while the reticulocytes (fig. 9) showed [an] irregular behavior.

Sixteen additional patients could be follow[ed] although more sporadically, for a sufficien[t] length of time to permit analysis. These case[s] together with the 4 described in the previou[s] paragraph, were treated statistically. The result was as follows: in 8 cases leukopeni[a] with less than 2,500 white cells/mm.^{3} deve[l]oped; the mean time interval between exposu[re] and lowest white count was 32 days, with [a] range from 11 to 52 days. Recovery above the 2,500 cell level occurred after a mean post[-]radiation time interval of 46 days, with a range from 12 to 81 days. Thrombocytopenia—platelet count below 70,000/mm.^{3}—was encountered in

TABLE IV

Effect of 200 r whole-body x-irradiation on the number of white blood cells, lymphocytes, and platelets in 1 mm.^{3} of blood. Means and standard deviations obtained from a group of 30 patients have been tabulated.

Time (days)	WBC (thousands/mm.^{3})		Lymphocytes (thousands/mm.^{3})		Platelets (thousands/mm.^{3})	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Pre-radiation						
1	9.62	4.48	1.45	.77	150	66
2	9.32	3.52	1.43	.82	154	68
3	9.33	4.27	1.36	.67	151	64
Irradiation						
0	9.65	3.85	1.16	.53	168	64
Postradiation						
1	9.14	3.45	1.00	.47	—	—
2	7.99	2.50	.88	.36	154	58
3	8.43	3.63	.81	.33	—	—
4	8.09	2.88	.73	.35	142	64
5	8.06	3.28	.78	.35	—	—
6	7.39	2.77	.64	.28	137	51
7	7.05	2.39	.69	.27	116	56
8	6.76	2.29	.71	.34	139	70
9	6.50	2.29	.69	.33	—	—
10	6.49	2.17	.68	.33	—	—

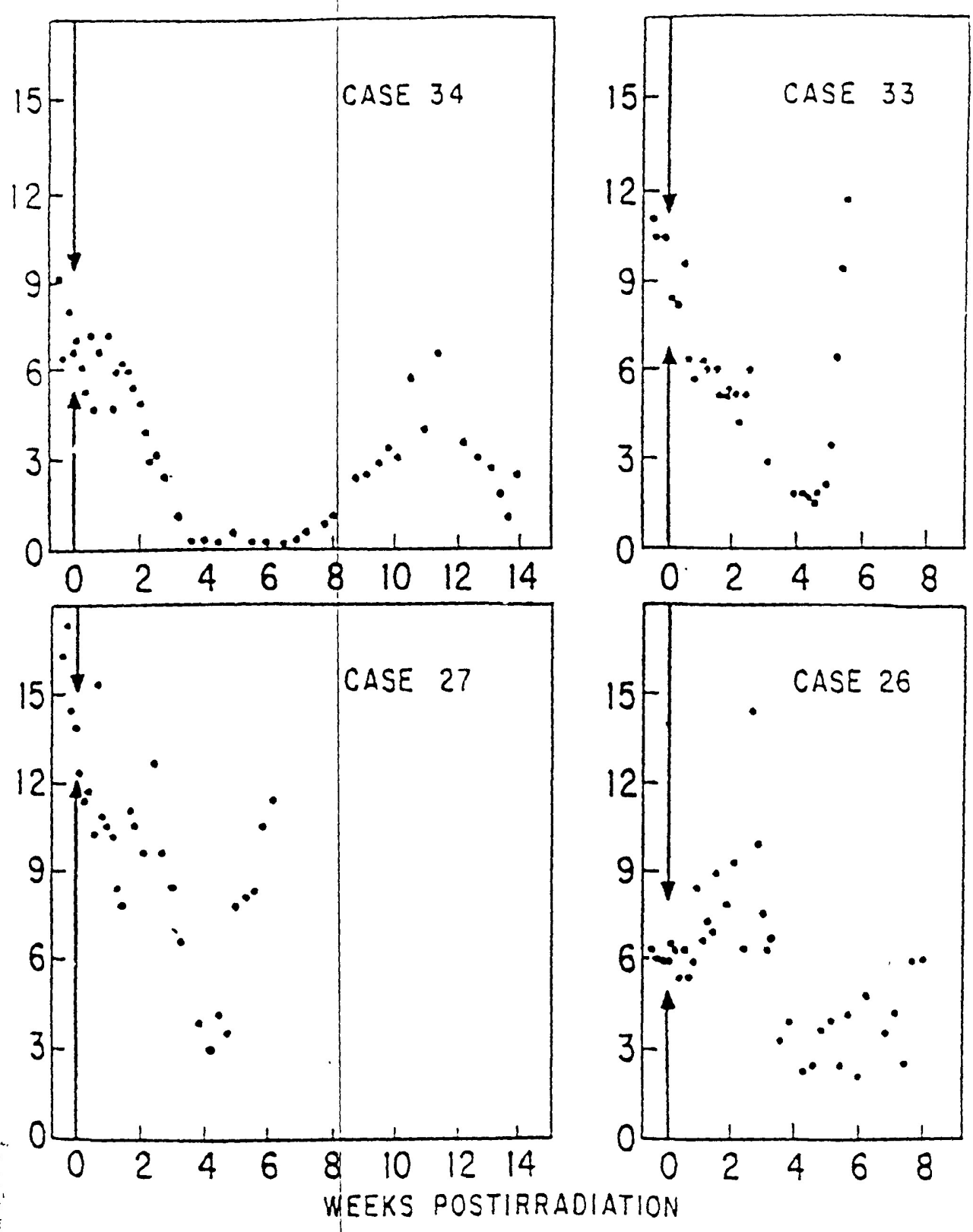


FIGURE 4

Effect of 200 r whole-body x-irradiation on the total white blood cell counts of 4 patients. Each dot represents one single determination. The arrows indicate the day of exposure.

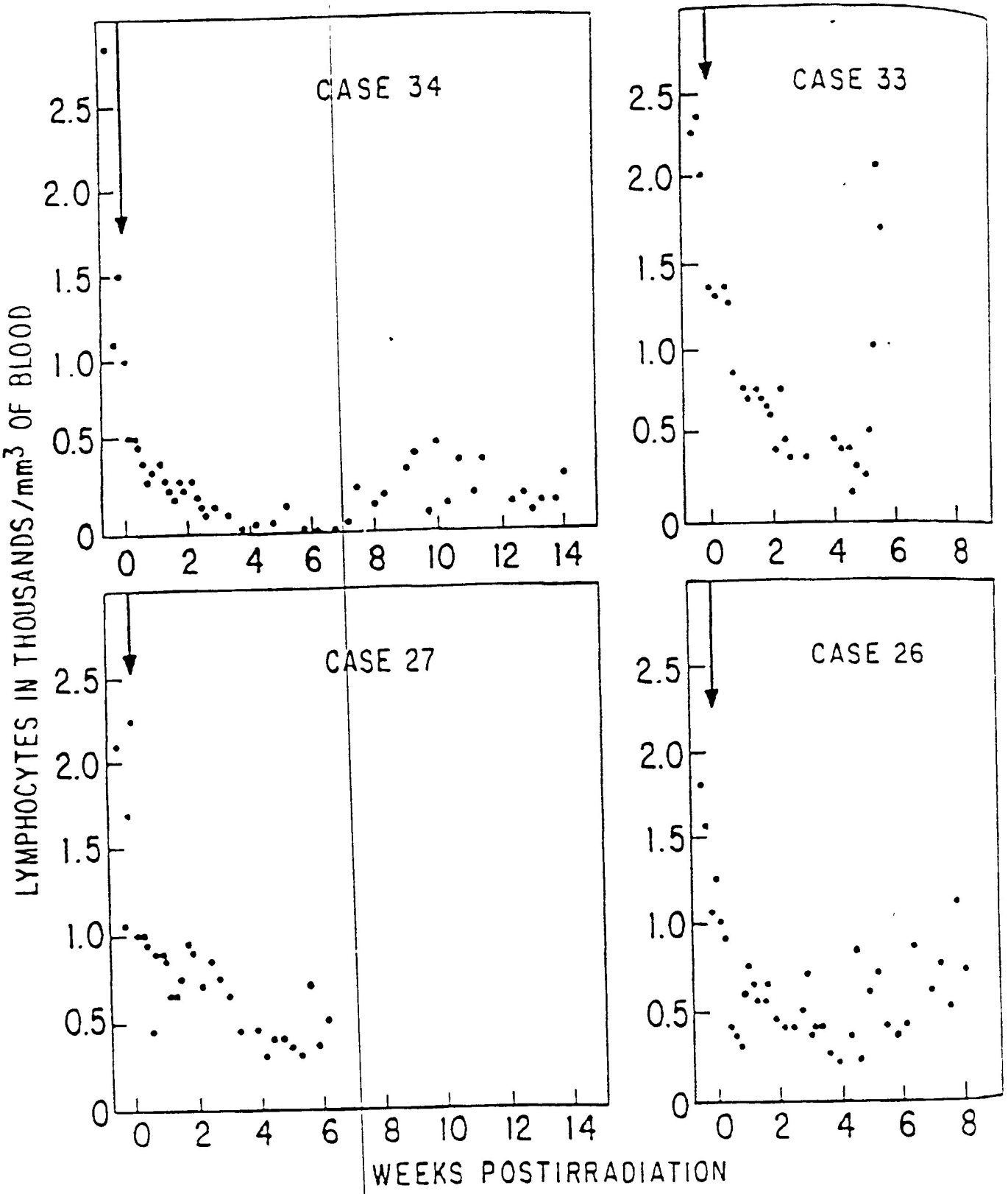


FIGURE 5

Effect of 200 r whole-body x-irradiation on the lymphocyte counts of 4 patients. Each dot represents one single determination. The arrows indicate the day of exposure.

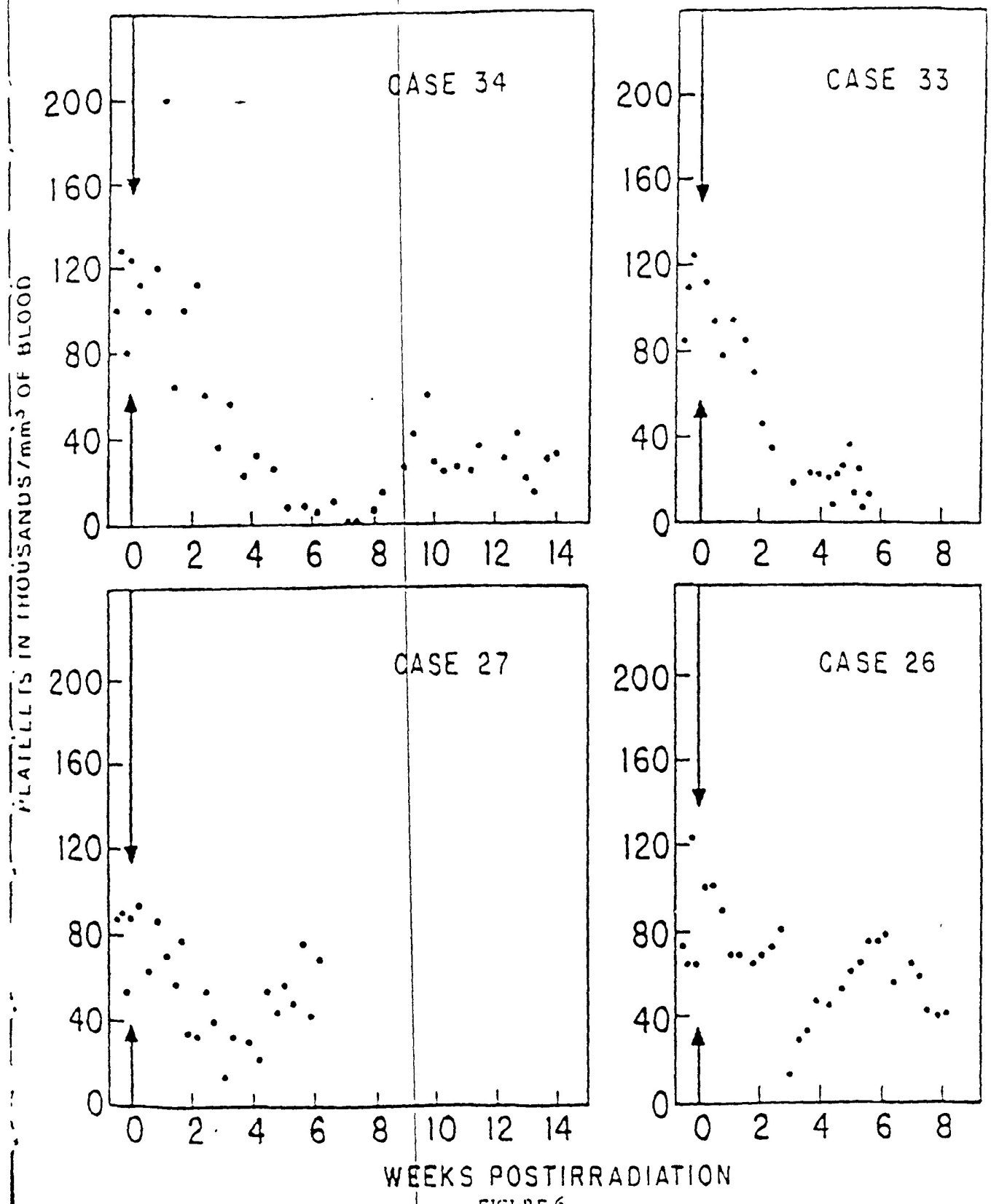


FIGURE 6

Effect of 200 r whole-body x-irradiation on the platelet counts of 4 patients. Each dot represents one single determination. The arrows indicate the day of exposure.

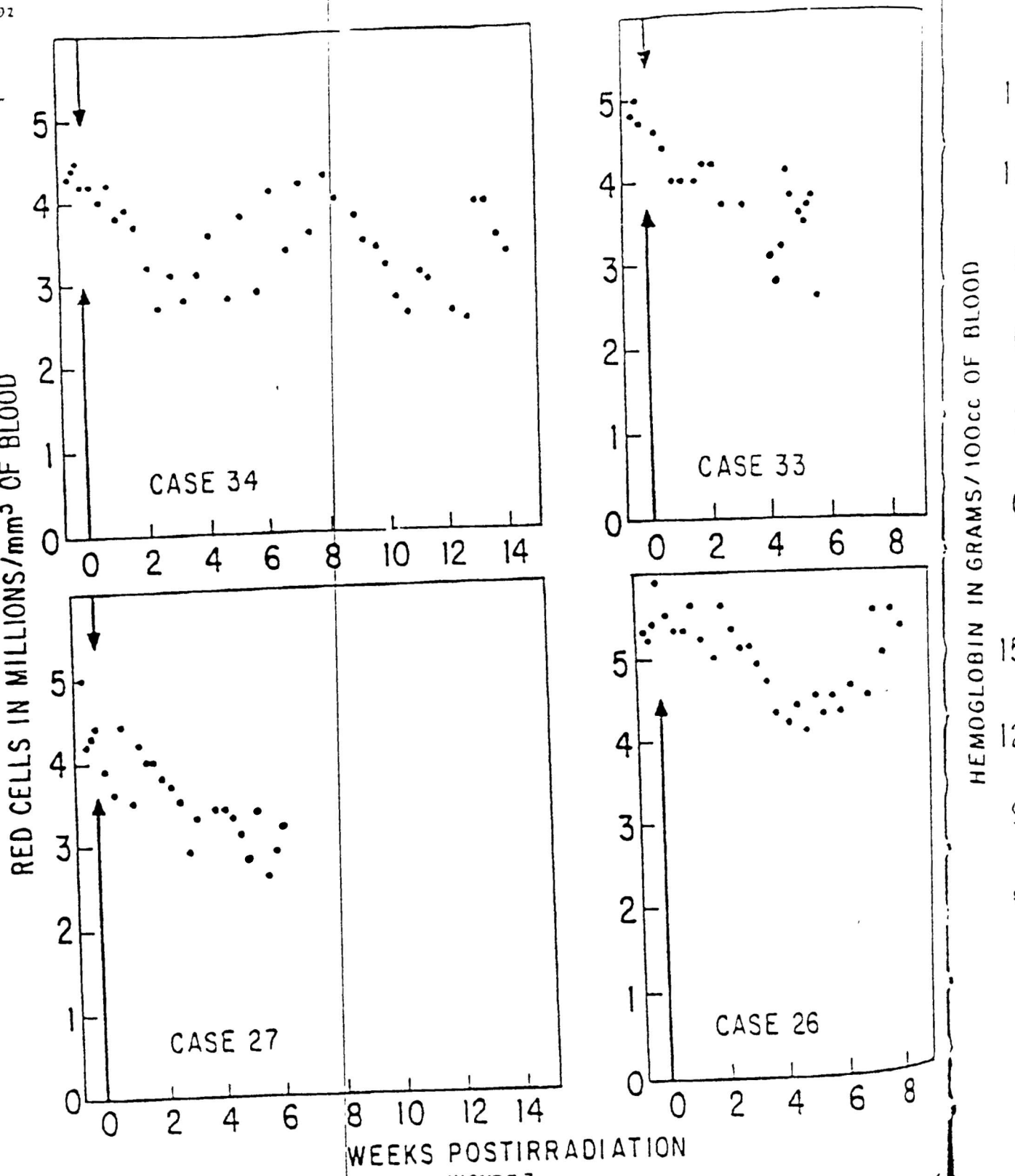


FIGURE 7

Effect of 200 r whole-body x-irradiation on the red blood cell counts of 4 patients. Each dot represents a single determination. The arrows indicate the day of exposure.

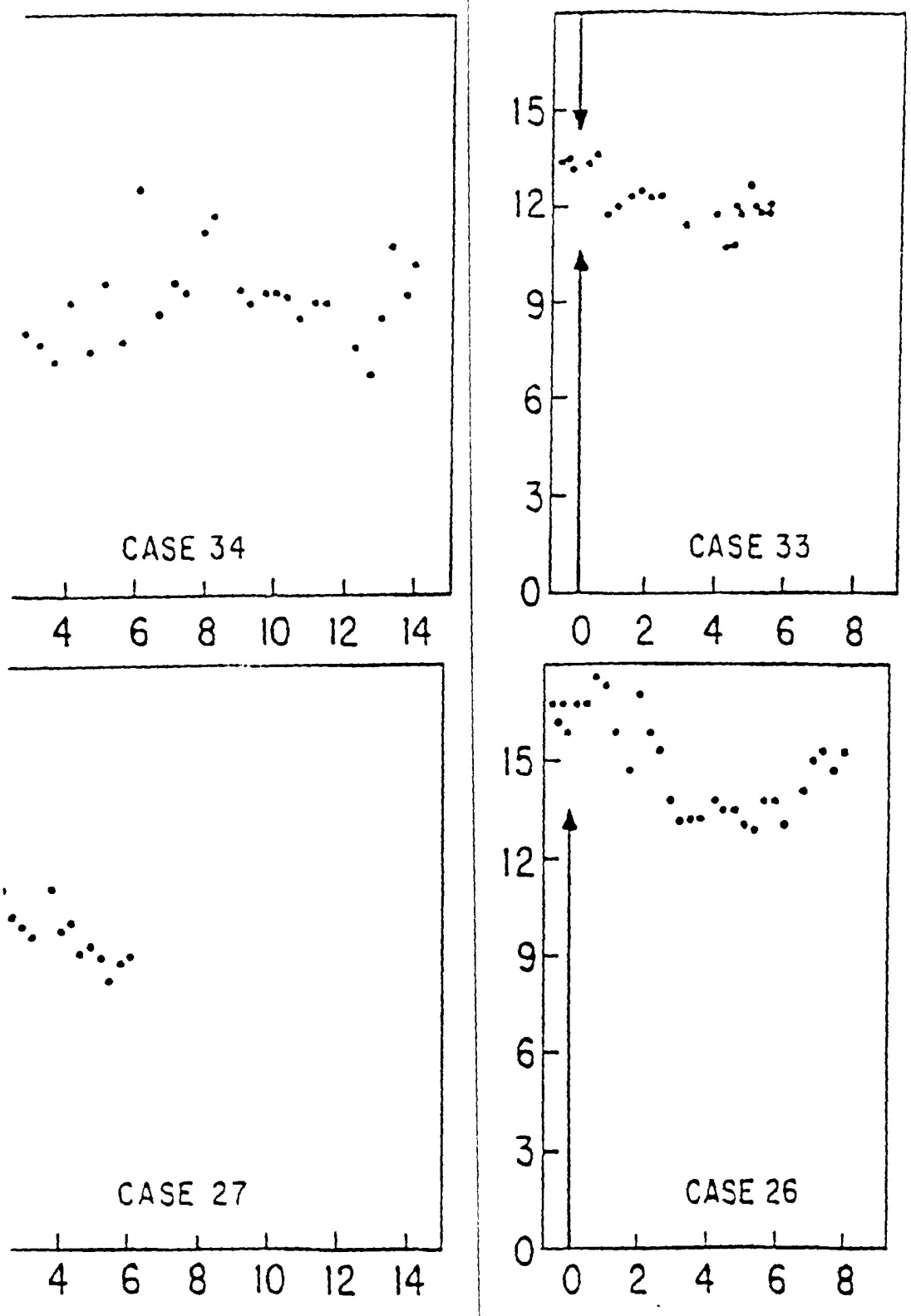


FIGURE 8

...bole-body x-irradiation on the hemoglobin levels of 4 patients. Each dot represents one ...n. The arrows indicate the day of exposure.

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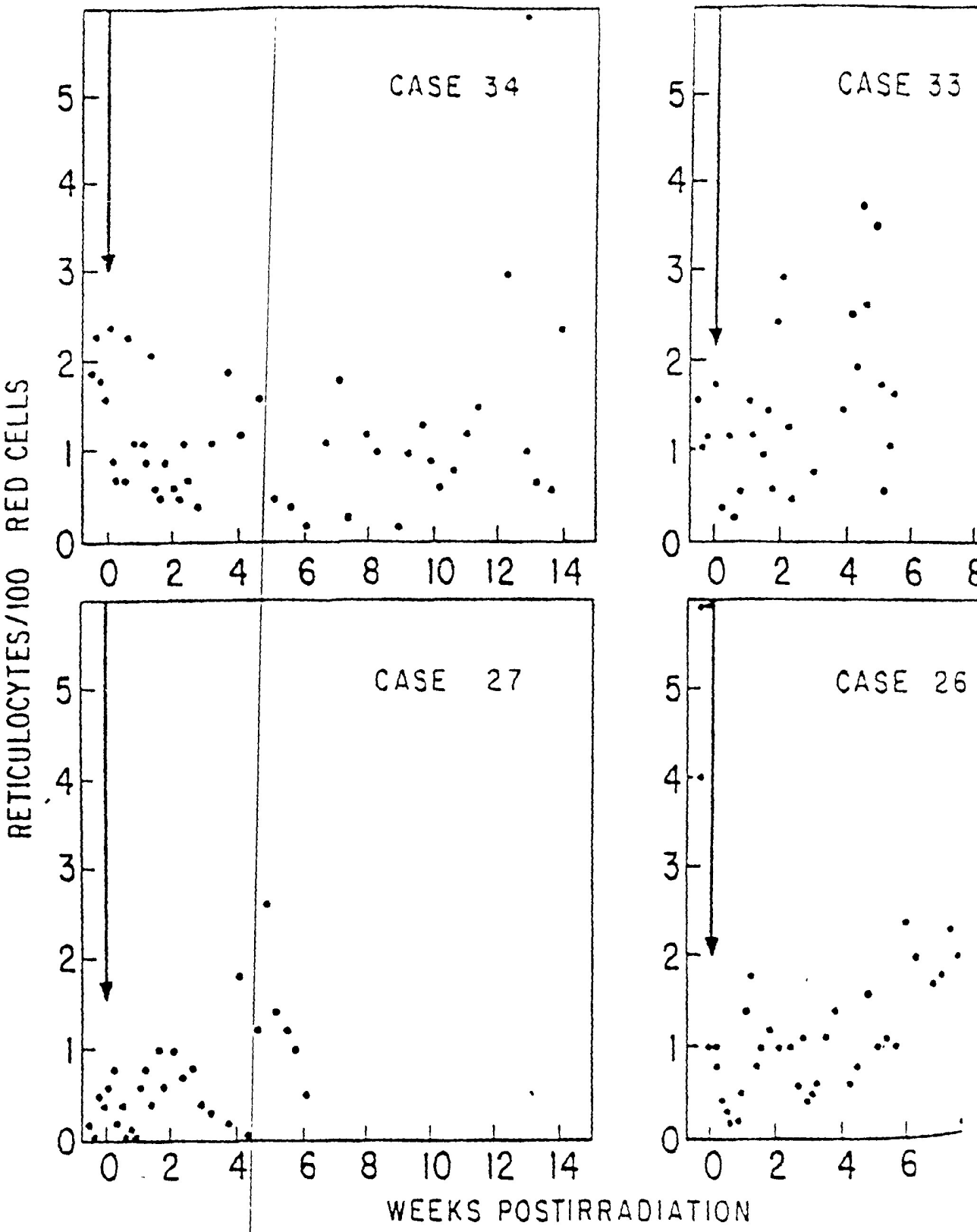

FIGURE 9

Effect of 200 r whole-body irradiation on the reticulocyte counts of 4 patients. Each dot represen single determination. The arrows indicate the day of exposure.

0 patients, however, it existed prior to ation in 4 cases. The mean time span n between exposure and lowest platelet count was 25 days, with a range from 8 0 days. Definite recovery above the 70,000 occurred only in 5 cases after a mean val of 59 days, with a range from 28 to days. Anemia, a hematocrit reduction of 0 to 5 volume percent as compared to pre-irradiation values, developed in 12 of 20 patients. A definite recovery occurring the 11th postirradiation week onward could demonstrated in only 2 of these cases. Anemia is a common occurrence in final cancer patients, it was difficult to e the causative or attributive role of liation in producing this long-lasting le- sion of red cells.

Complications. Macroscopic bleeding occurred sequent to irradiation in 19 of the 30 cases; ever, it should by no means be inferred t all, or even many, of these hemorrhages re due to radiotherapy. Hemoptysis was by the most common type of bleeding. It curred in 15 patients whose lungs, with 3 ceptions, contained either primary or stastatic tumors. In 7 of the 15 patients, cluding the 3 without known lung involvement, ere was no history of hemoptysis prior to tatment, and the postradiation hemoptyses ere unimportant with respect to blood loss. the remaining 8 patients, all with known ung involvement, hemoptyses preceded as ell as followed treatment; after irradiation e bleeding was somewhat increased in 1, d seriously accentuated in 3 of these cases.

Postradiation bleeding from extrapulmonary tumor sites occurred in 5 cases; however, it ad already been present prior to irradiation. Postradiation epistaxes without apparent cause ere reported by 4 patients. In 3 instances the leeding was brief and self-limited; it did not equire treatment and did not recur. The re- aining case was enigmatic. The patient had ad a cerebrovascular accident and occasional ild nosebleeds prior to irradiation. Epistaxes ntinued occasional until the 74th day after adiation when they began to occur daily. hereafter they persisted despite treatment y his family physician. The individual roles f disease and irradiation in bringing about the atient's epistaxes could not be established.

Bleeding into the skin—petechiae and/or ecchymoses—were seen in 4 patients, in each of these cases, however, whole-body x-irradiation was considered only one of the causative factors for the general hemorrhagic disorder. The bleeding occurred in a first case with terminal cardiac decompensation, in a second case with additional chemotherapy at three large doses of nitrogen mustard, in a third case with tense edema of the legs (ecchymoses in skin of legs only), and in a fourth case with additional rather high doses of limited field irradiation to the pelvic, abdominal para-aortic, and pulmonary areas prior to whole-body exposure.

In summary, 200 r whole-body x-irradiation seemed to increase the bleeding tendency in some of the patients, however, it did not cause alarming accidents.

Infection complicated the postradiation period only in *case 34*. This 55-year-old patient had lesions in the lungs, ilium, 12th rib, and 12th thoracic vertebra. Biopsy yielded a histologic diagnosis of undifferentiated malignant tumor, and autopsy revealed widely disseminated Hodgkin's disease. Several courses of limited field roentgen therapy provided temporary amelioration; in January 1956 whole-body x-irradiation was administered. Daily low-grade fever appeared on the 24th postradiation day, and antibiotic treatment with penicillin and streptomycin and, later, achromycin was started. A profound pancytopenia necessitated a series of whole-blood transfusions. Several gluteal abscesses and ulcerating lesions involving gingiva and hard palate developed; on culture they yielded beta-hemolytic *Micrococcus pyogenes*, var. *aureus*, resistant to achromycin. Therefore, the previous antibiotics were replaced by erythromycin, and gradual improvement took place. The patient became afebrile on the 51st day postradiation, the infectious lesions began to heal, and the leukocyte count rose to 2,300 from a previous minimum of 100.

Life expectancy. All 30 patients of the final 200-r group died within 20 months; mean survival time was 4.1 months. Because of the wide individual variability in the group as to age as well as to tumor type (table 1), and because of lack of an untreated control series of similar composition, it was difficult to assess the

extent to which radiation had affected the life expectancy of the patients, however some estimate was possible. The 12 cases of bronchogenic carcinoma, representing a relatively uniform population, were separated from the rest of the 200-r series and were compared with data available in the literature. In these 12 patients the carcinoma was too advanced to be operable or to be suitable for radical radiotherapy, even palliative irradiation in its ordinary form was not considered promising. In 3 instances diagnosis was based on both roentgenologic demonstration of lung or mediastinal abnormalities, consistent with bronchogenic carcinoma, and on biopsy reports of malignancy from either the chest wall or a supraclavicular lymph node; in the remaining cases diagnosis was confirmed by bronchoscopic biopsy in 2, by biopsy at thoracotomy in 3, and by histologic examination at autopsy in 4. Mean survival time after 200 r whole-body x-irradiation in these 12 cases was 3.5 months. Rienhoff (11) reported a life expectancy of "approximately 5 months" for a group of 344 patients, "many" of whom had received local radiotherapy after irremovable tumors had been found at chest exploration. Watson (12) found in 295 untreated lung cancer patients a mean survival time of 3.1 months. In figure 10, the survival distribution of the present series of

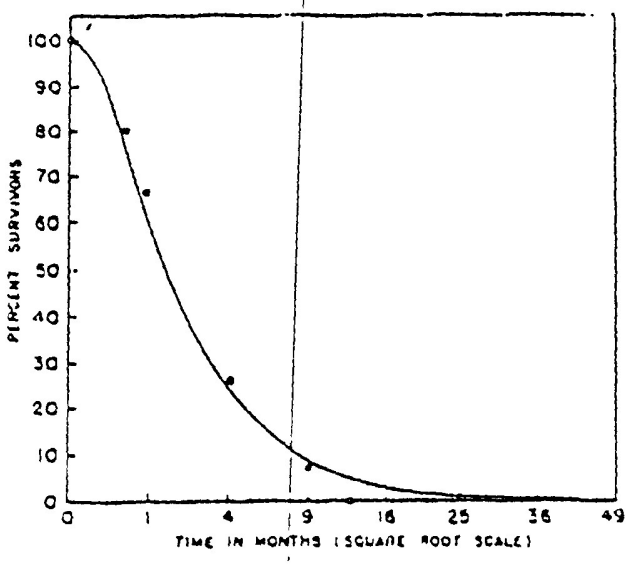

FIGURE 10

Life expectancy of advanced lung cancer patients. The curve represents Watson's untreated series of 295 cases (ref. 12, fig. 1), while the open circles are derived from 12 lung cancer patients exposed to 200 r whole-body irradiation.

12 lung cancer patients was compared wi
of Watson's untreated group (ref. 12, fi
What interpretation should be given t
surprising coincidence between the two
of data in figure 10? Obviously, life expec
was determined largely by the state o
malignancy, and therefore by the standar
selection of cases. Under the reason
assumption that the present series showe
least as advanced a state of disease
Watson's untreated series, the conclusion
be reached that *200-r whole-body x-irradi
either did not affect at all the life span o
patients, or might even have caused a s
prolongation.*

Any comparison of survival times bet
the final 200-r group and the exploratory gr
was meaningless, obviously, since the stan
for selection of patients shifted mark
during evolution of this study as descr
under "Method."

2. Brief survey of the exploratory phases

The first exploratory group consisted
199 patients exposed to doses ranging fro
to 75 r. Treatment was well tolerated in
cases. With the exception of one patient,
experienced a brief episode of nausea on
day of irradiation, no member of the g
reported complaints characteristic of the abo
described early reactions. Since during
phase, as described under "Method," wh
body irradiation was used only as an adjuv
to established types of therapy, a decai
hematologic analysis was not perform
Gross examination of the data indicated ir
ular fluctuations probably caused by dise
and conventional treatments. There seemed
be no significant enhancement of life exp
tancy, as revealed by the following con
erations: The first exploratory phase en
in the spring of 1953. Review of the hosp
records, at 3 years after conclusion of
phase, showed that 70 percent of the pati
were dead, or presumed dead, while 30 per
were living. Thus, at the time of su
approximately one-third of the group were
between 3 and 5 years after whole-body
posure. Such a survival rate was not bel
significantly greater than that expected wi
whole-body irradiation as an adjuvant, as j
from clinical experience.

ext group consisted of 18 patients
co 100 r. Results were essentially the
in the preceding series; however, there
me hematologic changes definitely
by whole-body x-irradiation during the
bservation period (table V). For statis-
luation, the group means of the mea-
s on each postradiation day were
l with the corresponding values letter-
days prior to exposure, and Student's
as applied to the differences. This
e yielded the following result: neither
hite blood cell counts nor platelet
showed any radiation effect, while a
lymphocytes occurred which became
ant on the 0.01 level after the second
ation day.

hird exploratory group consisted of 17
exposed to doses as follows: 125 r,
4; 150 r, 6 cases; 175 r, 1 case; and
5 cases. Since the number of patients
for each dose level was too small for analysis, the 125 r, the 150 r, and 175 r cases were pooled; the five 200 r cases were excluded from the pool since their data had been partially considered in the preceding section. The following observations were made on the 12 pooled 125- to 175-r cases: Early reactions were easily recognized; 7 patients vomited and 4 did not, while no record was available in the remaining case. Definite hematologic changes occurred during the initial 2-week observation period (table VI). Statistical evaluation with the above-described procedure showed a drop in total leukocyte count which became significant on the 0.01 level after the seventh postradiation day, a decline in lymphocytes which became significant after the fourth postradiation day, and no change in thrombocytes. Clinically significant complications, as described for the final 200-r group, were not encountered.

TABLE V

Effect of 100 r whole-body x-irradiation on the number of white blood cells, lymphocytes, and platelets in 1 mm.³ of blood. Means and standard deviations obtained from a group of 18 patients have been tabulated.

Time (days)	WBC (thousands/mm.³)		Lymphocytes (thousands/mm.³)		Platelets (thousands/mm.³)	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Pre-radiation						
1	7.19	3.02	1.47	.74	202	80
2	7.49	3.08	1.45	.63	196	79
3	8.18	2.71	1.50	.64	188	51
Irradiation						
0	7.59	2.16	1.16	.52	203	82
Postradiation						
1	7.94	2.52	1.09	.40	—	—
2	7.41	2.47	.86	.31	187	80
3	7.54	2.94	.88	.39	213	36
4	7.62	2.96	.95	.46	196	92
5	7.73	3.21	.91	.43	223	58
6	7.69	3.96	.79	.34	211	58
7	6.79	2.72	.73	.37	246	34
8	7.49	4.18	.84	.37	171	43
9	7.05	2.69	.76	.32	223	91
10	6.91	2.74	.85	.41	188	31

To obtain a gross estimate of the dose dependency of the hematologic changes, the group means in percent of their pretradiation level were represented graphically (figs. 11 and 12). This procedure showed that the fall in total white blood cells became more pronounced with increasing dose (fig. 11), while the reduction in lymphocytes was practically independent of dose (fig. 12).

3. Double exposures

Eight patients, who seemed to have improved after the first whole-body irradiation, received a second treatment when deterioration again began; the interval between the two exposures varied from 77 to 187 days. The following dose combinations were used: 50 + 50 r (1 case), 100 + 150 r (3 cases), 125 + 150 r (1 case), 150 + 150 r (1 case), 175 + 175 r (1 case), and 125 + 200 r (1 case). The number of patients in this series was too small to allow definite conclusions. The following impression was gained, however responses to the second [illegible] seemed more pronounced than those follow the first. This apparently was true for initial reactions—fatigue, anorexia, naus and vomiting—as well as for the delayed bo marrow depression. Following the first do the instances of clinically significant leuk penia, thrombocytopenia, and anemia, as defin above, were as follows: 0, 2, and 5, respe tively, following the second dose they we 3, 5, and 5, respectively. Since the seco dose was larger than the first in 5 of the patients, the greater response following exposure might be explained on this bas alone. However, two impressions seemed indicate a true increase in general radiose sitivity persisting even several months af application of the initial dose. First, enhanc reactions occurred also in those 3 patie who had received a second dose that was eq to the first in size; and second, aggravation reactions seemed indicated when respons

TABLE VI

Effect of 125-175 r whole-body x-irradiation on the number of white blood cells, lymphocytes, and platelets in 1 mm.³ of blood. Means and standard deviations obtained from a group of 12 patients have been tabulated.

Time (days)	WBC (thousands/mm.³)		Lymphocytes (thousands/mm.³)		Platelets (thousands/mm.³)	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Pre-radiation						
1	8.68	2.35	1.16	.50	198	65
2	7.95	1.79	1.30	.41	228	77
3	8.76	2.32	1.39	.37	274	87
Irradiation						
0	8.11	1.84	1.39	.32	237	97
Postradiation						
1	8.50	2.30	1.11	.38	—	--
2	8.54	2.81	.94	.24	231	78
3	7.27	1.36	1.00	.29	192	70
4	7.07	1.68	.83	.24	262	98
5	7.10	1.91	.90	.41	180	80
6	6.63	1.62	.92	.39	—	—
7	6.41	1.55	.86	.30	204	76
8	6.05	1.13	.83	.29	—	—
9	6.02	1.24	.79	.38	202	83
10	6.03	1.17	.79	.24	191	52

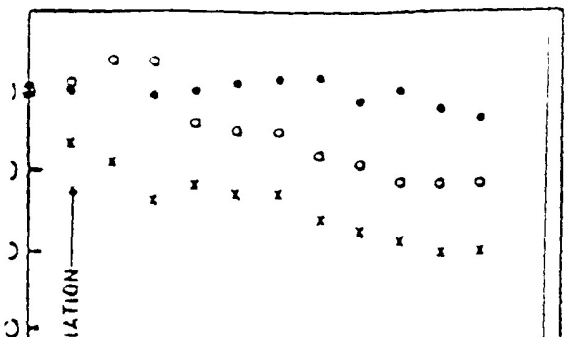

FIGURE 11

...e dependency of the effect of whole-body diation on the total white blood cell count. ...arkings denote the following: dots, statistical ...s derived from 18 patients exposed to 100 r; ... circles, statistical means derived from 12 ...nts exposed to doses between 125 and 175 r; and ...es, statistical means derived from 30 patients ...sed to 200 r.

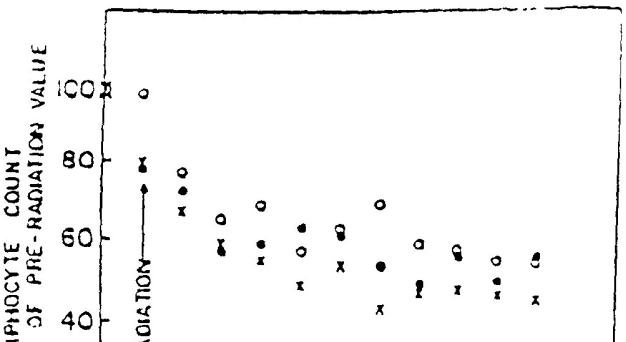

FIGURE 12

Dose dependency of the effect of whole-body x-irradiation on the lymphocyte count. The markings denote the following: dots, statistical means derived from 18 patients exposed to 100 r; open circles, statistical means derived from 12 patients exposed to doses between 125 and 175 r, and crosses, statistical means derived from 30 patients exposed to 200 r.

he second dose were compared with those ...aring in patients who had received a single ...sure of corresponding size. Loeffler (13) ...e similar observations and explained them ...a reduction of the body's capacity to repair ...ation-induced cell damage.

DISCUSSION

...iologic actions of ionizing radiation become ...e and more objectives of two different ...lds. The first, radiotherapy, utilizes such ...ions for curing disease in human patients; ... second, radiobiology, attempts to discover ... explain these actions by experimental ...ns. The two fields of endeavor have accu...lated a wealth of information which, when ...perly exchanged, may prove fruitful and ...ulating to each other. To foster such an ...change, the radiotherapist has to record ...servations that are often clinically of little ...nificance, and to present them in a form ... enables comparison with findings obtained ... accidental irradiation of healthy human ...gs and from animal studies. The present ...ort attempts a step in this direction.

On the one hand, the data of this report are well suited for comparison because of the exposure conditions under which they were obtained. Lateral irradiation by two opposing fields produces a rather homogeneous dose distribution through the body (9); thereby, it approximates conditions existing during the unilateral exposure of small laboratory animals to radiation of comparable penetration and also those during human exposure to radiation of much higher penetration such as produced by cobalt-60, cesium-137, and nuclear explosions. On the other hand, the present data are limited in their general radiobiologic value because of the unpredictable distortion superimposed by disease; therefore, great caution must be exercised in drawing far-reaching conclusions. Although a thorough comparative analysis of the data lies beyond the scope of the present report, a general impression may be given. Close similarity seems to prevail between the systemic effects produced in cancer patients by whole-body x-irradiation and those caused in healthy human beings by nuclear explosions. Both type and time-course of the biologic

reactions appear to agree well, however, there may exist a difference in degree. Understandably, the terminal cancer patient with his spontaneous tendency toward vomiting, bone-marrow depression, and hemorrhage may be expected to have an increased radiosensitivity with respect to induction of these symptoms. This restriction should be applied to the summarizing statements of the next paragraph.

Systemic and clinical effects induced by whole-body x-irradiation occur essentially in two phases that may demand special medical attention. The first one, the initial reaction, is characterized by fatigue, anorexia, nausea, and vomiting. In typical cases, it begins approximately 2 hours after exposure and subsides 24 hours later. As shown by Court Brown (14), a strong psychologic component may frequently be involved. The second phase, a more or less pronounced bone-marrow depression, is characterized by a tendency toward bleeding, infection, and pancytopenia. In typical cases, it becomes significant clinically 3 to 4 weeks postirradiation and begins to subside 6 to 8 weeks after exposure. Generally, doses of 100 r or lower are subthreshold and will not produce these reactions. In the dose range between 125 and 175 r the two phases begin to appear in about 50 percent of the cases; however, the reactions are too mild to demand countermeasures other than [illegible] reassurance. At 200 r, the two phase[s] clearly recognizable in about 80 percent [of] cases; and reactions are sufficiently [severe] to require clinical treatment in about 10 [percent] of the patients. Thus the threshold dose, [above] which in a small percentage of patients [severe] complications begin to appear, lies [somewhere] between 150 and 200 r.

SUMMARY

A series of 263 cancer patients [received] whole-body irradiation with doses ranging [from] 15 to 200 r. Critical evaluation of the procedure as a therapeutic tool was excluded from this report; its scope was limited essentially to acute and subacute effects, so far as they are systemic in nature. These effects—predominantly nausea, vomiting, and bone-marrow depression—were practically absent below 100 r; they became noticeable between 125 and 175 r; and they developed into complications requiring clinical treatment in 10 percent of the patients at 200 r.

The authors are indebted to Major General O. O. Benson, Jr., Dr. R. Lee Clark, Jr., and Colonel J. K. Pickett for advice and support; to Dr. J. F. Dillon and Dr. [illegible] for conducting the major part of the exploratory [study]; to E. Macdonald for statistical evaluation of the data; and to P. McIntyre for the laboratory examinations.

REFERENCES

1. Liebow, A. A., S. Warren, and E. DeCoursey. Pathology of atomic bomb casualties. Am. J. Path. 25:853-1027 (1949).

2. Hempelmann, L. H., H. Lisco, and J. G. Hoffman. The acute radiation syndrome: A study of nine cases and a review of the problem. Ann. Int. Med. 36:279-510 (1952).

3. Heublein, A. C. A preliminary report on continuous irradiation of the entire body. Radiology 18:1051-1062 (1932).

4. Hedinger, F. G., and L. F. Craver. Total body irradiation. Am. J. Roentgenol. 48:651-671 (1942).

5. Collins, V. P., and R. K. Loeffler. The [palliative] use of single doses of total radiation. Am. J. Roentgenol. Radium Therapy Nuclear Med. 75:542-547 (1956).

6. Loeffler, R. K., V. P. Collins, and G. A. [Jones]. Comparative effects of total body radiation, nitrogen mustard, and triethylene melamine on the hematopoietic system of terminal cancer patients. Science 118:161-163 (1953).

7. Osgood, E. E., and A. J. Seaman. Treatment of chronic leukemias. J.A.M.A. 150:13[illegible] (1952).

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28

ler, [illegible], G. H. Fletcher, and W. K. Sinclair. Therapeutic value of whole-body x-irradiation for patients with generalized neoplastic disease. (In preparation)

clair, W. K., and A. Cole. Technic and dosimetry for whole-body x-irradiation of patients. School of Aviation Medicine, USAF, Report No. 57-70, Mar. 1957.

clair, W. K. Change in plasma clearance rate and red cell uptake of radioactive iron in patients following total body x-radiation. School of Aviation Medicine, USAF, Report No. 57-116. (In press)

11. Riennoff, W. F. A clinical analysis and follow-up study of five hundred and two cases of carcinoma of the lung. Dis. of Chest 17:33-55 (1950).

12. Watson, E. A. Supervoltage roentgen therapy in cancer of the lung. Am. J. Roentgenol. Radium Therapy Nuclear Med. 75:525-529 (1956).

13. Loeffler, R. K. Radioiron tracer studies for the evaluation of radiation damage. Presented at the annual meeting of the American Radium Society, 1956.

14. Court Brown, W. M. Symptomatic disturbance after single therapeutic dose of x-rays. Brit. M. J. 1:802-805 (1953).

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Conference on Dosimetry of Total-Body Irradiation by External Photon Beams

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DOSIMETRY OF TOTAL-BODY IRRADIATION BY EXTERNAL PHOTON BEAMS

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Introduction

A conference on total-body dosimetry, attended by physicists, radiobiologists, and clinicians* was held at Oak Ridge Associated Universities (ORAU) on February 23 and 24, 1967, under the auspices of the National Aeronautics and Space Administration (NASA)† and ORAU.‡ Its purpose was to review work on total-body irradiation, and if possible to arrive at a consensus on a uniform way of reporting the doses delivered. Discussion was restricted to photon irradiation, with emphasis on the physical rather than on the biological aspects.

Although much of the work had appeared in the open literature, some of it first came to light during the conference. The meetings were informal and as much time was allotted to discussion as to presentation of papers. The authors of the present paper were the organizers and also served as rapporteurs. What follows is their view of what took place; it does not follow exactly the order in which the talks were given. Instead the topics are divided into two groups: I. Methods of irradiation; and II. Measurement and calculation of dose.

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* Appendix I gives the participants and the program.

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PART I: METHODS OF IRRADIATION

After a welcome by Andrews and introductory remarks by Cloutier, Lushbaugh stated that the aim of the ORAU survey, undertaken on behalf of NASA, is to establish a quantitative relation between radiation dose and a number of biological responses in man. Retrospective studies on the case histories of all known patients exposed to total-body irradiation, both in the United States and abroad, are under way and future studies are in prospect. Lushbaugh expressed the hope that some uniform method of reporting the dose received by irradiated patients would be agreed upon as a result of the present meeting, and that the method would be widely used in future studies. He described the methods used in seeking out information for the ORAU-NASA survey and stressed that considerable difficulty arose in interpreting records, particularly if the work reported on had been carried out many years ago. No two institutions used the same system of reporting, and many vital items in both dosimetric and medical histories, originally thought to be unimportant, were now irretrievably lost.

He reported that the average dose and the exposure at the midline in the absence of the subject were most frequently used to describe the patient's total-body irradiation. Several other radiation units were also used; the one Lushbaugh favored was what he called "epigastric dose"; that is, the number of rads delivered to the upper abdominal compartment. He pointed out that this quantity was the variable with which the severity of systemic symptoms seemed to be most readily correlated. In replying to a question by Focht, Lushbaugh stated that at ^{137}Cs energies the number of rads delivered to the epigastrium is, in persons of normal size, approximately 0.66 times the exposure (R) that would have existed at the position of the epigastrium if the patient's body were removed.

Another objective of the present study is to change the rather widely held concept that a specified dose level invariably brings about a certain physiological response. Thus, the statement that 200 R would invariably induce vomiting should be replaced by a statement of the probability that 200 R would cause vomiting. Lushbaugh then outlined the system of probit analysis used at ORAU to correlate "go, no-go" phenomena, such as vomiting or diarrhea, with the dose that would induce these effects with a certain probability.

From initial analyses of a limited number of cases, which give remarkably consistent results, it is possible to estimate for any effect E, the dose ED_x that causes the effect to occur with a probability of x percent.

Beck then summarized the material available for analysis. It now consists of about 1800 cases located at 38 institutions (Table I). For the NASA study any number of irradiations given on the same day were considered as one treatment. One or more irradiations given in a period of one week constitute an intermediate group. Multiple irradiations extending beyond one week are considered as a fractionated treatment, and irradiations separated by six weeks or more are considered as separate treatment series. The collaborating institutions, on the other hand, used quite different conventions.

Questions from Shonka and others brought out that most of the ORAU patients had suffered from leukemia or lymphomas but patients from other institutions generally had epithelial neoplasms. It also emerged that some patients had been exposed to more than 1000 R in a single day, although in the vast majority the exposure had been much less.

Typical Total-Body Irradiators

Beck then described the radiation equipment used at collaborating institutions. As a general rule, the older work was done with X-ray equipment not specifically designed for total-body irradiation, whereas the more recent equipment tended to be custom-built and relied predominantly on gamma rays. Only fragmentary dose data existed for patients treated in the 1930's, whereas dosimetric information for patients irradiated in recent years was generally in more detail.

As typical arrangements, Beck chose to describe those at ORAU, Peter Bent Brigham, Mary Imogene Bassett, and City of Hope Hospitals. In the ORAU installation, the early work was done with a ^{60}Co source enclosed in a spherical shield. Most of the patients, however, have been treated in a later irradiator (1) with multiple ^{137}Cs sources, providing remarkably uniform exposure over the treatment area (2). Exposure rates available were between 0.7 and 2.0 R/min. Results were recorded as midline air exposure, average abdominal dose, or total-body average dose. The City of Hope Hospital in Duarte, California, also has a specially-built installation with eight ^{137}Cs sources. The exposure rates were between 0.02 and 4.7 R/min. Results were given

as "average midplane, midbody dose" (*3*). At the Peter Bent Brigham Hospital, in Boston, Massachusetts, multiple portals were used to cover the whole body. A 250-kV machine was used with an exposure rate of 5.5 R/min; the midbody depth dose was recorded (*4*). The irradiator at the Mary Imogene Bassett Hospital, Cooperstown, New York, consists of two ^{60}Co sources with the patient in between. Exposure rates ranged from 6 to 25 R/min. Both exposure and depth dose at the center of the body were given (*5*).

In the first invited paper, Shalek described the 250-kV X-ray facility used at the M. D. Anderson Hospital during the 1950's for the irradiation of 263 patients. The half-value thickness (HVT) was 3 mm Cu. The patients were placed 275 cm from the X-ray target and irradiated laterally while in a crouched position. The "edges" of the beam (taken to coincide with the 50% isoexposure line in air) enclosed an area of 1200 cm^2, which was large enough to accommodate the crouching patient. After one-half of the exposure had been given, the patient was turned and irradiated from the opposite side. The dose within the patient varied ±20% with the minimum dose at the patient's center. The exposure rate was 3.8 R/min. Both the exposure at midline and the average dose, calculated by one of Mayneord's formulas were reported for all patients (*6*).

At Baylor University in Dallas, West reported that the initial irradiations had been performed with a 220-kV X-ray machine while the patient lay on a stretcher. Half the exposure was given AP and the other half PA. The surface dose was taken as 100% (*7*). The exposure rate was 5 R/min. Later, X rays from a 2-MeV accelerator were used with the patient sitting up in a rotating chair. The dose at the center of the body was calculated to be 68 to 72% of the air exposure. Integral doses were also calculated by Mayneord's equations, correcting for nonuniformity of the beam (*8*).

Hayes presented details of dose measurements carried out at the ORAU irradiator with three anthropomorphic phantoms corresponding to three typical body sizes: a small child, an adolescent, and an adult. The complete isodose distribution (Fig. 1) within the phantom was determined with an ionization probe. In addition, chemical dosimetry was used to measure the average dose to the whole body and for separate body compartments. The integral dose calculated graphically from the isodose lines differed by less than 5% from the values obtained with the chemical dosimeter.

A comparison was also made, with the same phantoms and chemical system, of the average dose in various body

compartments when exposed to radiation from two temporary ^{60}Co irradiators used at ORAU during the early total-body irradiation studies. There was less variation in average dose from one compartment to the other with the eight ^{137}Cs-source facility than with the bilateral ^{60}Co radiation setup (*9*).

Kereiakes reported that the irradiator at the Cincinnati General Hospital consisted of a single ^{60}Co source housed in a teletherapy head. The patient was placed in a sitting position, the lower extremities were raised, and the head was tilted forward. In this way the patient was made to fit within the 50% isoexposure line of the beam. The distance from source to the patient's center was 282 cm. One-half the dose was administered from one side, the patient was rotated, and the remaining dose was given. The exposure rate was 3.5 to 6 R/min at the center of the body, in the absence of the patient. Skin doses were calculated and verified by means of ionization chambers and lithium fluoride dosimeters. Depth-dose measurements in a masonite phantom indicated that dose variation in the trunk of a typical patient was only ±8%. Dosage was expressed as rads at the patient's midline (*10*). More recently, integral doses have been calculated by Mayneord's method. For a given midline dose, the integral dose varies depending upon the patient's lateral dimensions.

Campbell reported that the total-body irradiator at the Manitoba Cancer Treatment and Research Foundation, Winnipeg, Canada, provides a uniform exposure rate (±2.4%) within a cylindrical treatment volume 6 feet high with a base diameter of 8 feet. The uniformity becomes ±4% if the base diameter is increased to 10 feet. The uniform field is produced by six ^{60}Co sources; four of them, positioned at the midplane of the irradiation volume, provide 99% of the exposure; two small sources one above and one below the treatment volume provide the remaining 1% of exposure. The exposure rate is about 0.5 R/min. The facility has not been placed in routine use for patients. Depth-dose measurements in phantoms have not been done (*11*).

Focht described the irradiator that Heublein and Craver used in the 1930's at Memorial Hospital, New York. Since dosimetry was not then very advanced, accurate dose estimates could not be made. Dosage was given at that time in erythema units. On the basis of available information about the X-ray machines (kilovoltage, milliamperage, etc.), Focht has estimated the doses in rads that the patients had received. Although it is difficult to assess the accuracy of the estimates, the data are unique in that they represent

observations for low exposure rates and low-energy radiation, whereas most other work was carried out at higher exposure rates and at higher energies.

Comments

The preceding presentations, together with data from other institutions that were not represented at the meeting, may allow a few generalizations.

1. Several techniques of total-body irradiation have been used. The most common one has been to irradiate the patient with a single beam of X rays generated at about 250 kV. The patient was usually two or three meters from the X-ray tube. The exposure was given AP-PA or from each lateral side of the patient. Dose uniformity within the body was from ±15 to ±30%.

2. Several investigators used the same technique but with ^{60}Co gamma rays or 2000-kV X rays. Dose uniformity within the body was between ±8 and ±15%.

3. Special facilities using eight ^{137}Cs sources gave a dose uniformity within the body comparable to that obtained with opposing beams at about 1-MeV.

4. The exposure rates were generally between 1 and 6 R/min.

5. Dose has been reported in a variety of ways, and many institutions use more than one expression. Exposure (usually at the patient's midline) is by far the most common figure given. Dose estimates in use are (a) midtrunk dose; (b) integral dose; (c) average dose; (d) midplane, midbody dose; (e) skin dose; and (f) epigastric dose.

Evaluation of Reported Dose

Comas, Beck, and Cloutier explained how they attempted to unify the dosimetry of all patients treated with total-body irradiation in the 38 institutions of Table I. The first step was to select dose expressions that would be common to all patients.

Of the available choices, the average total-body dose appeared to be open to the fewest objections and was calculated when sufficient data were available from the

patients' records. Lushbaugh is using this dose expression in current attempts to correlate dose and response.

The midbody dose was also calculated but has the objection that it represents the dose to only a small fraction of the body tissues (see Fig. 1).

Target-organ dose, although an appealing concept, has the drawback that the identity of the organ responsible for a specific biological effect is generally not known and, if known, the organ's dose is difficult to calculate. On the assumption that the prodomal syndrome is related to the dose absorbed in the upper abdomen, "epigastric doses" were computed for those patients on whom enough information was available. Lushbaugh used this dose estimate in his early attempt to correlate dose and response.

Exposure and integral doses were also calculated if data were available. Objections to these dose expressions had been well explained in the report of Sinclair and Cole (*6*): "It is evident that we cannot accurately compare the effects produced in animals and humans, or even in different human beings, by means of either the air dose or the integral dose . . . We would not, for instance, consider that a very large man, placed at the point where 200 R might be measured in air, experiences a much greater effect because the integral dose to his body is much greater than that of a man only half his weight."

In this connection Robinson argued that the average total-body dose could also be misleading. For example, suppose that several kilorads were given to only the foot. Here the average total-body dose might still be hundreds of rads; however, the systemic response would clearly not correlate with the average total-body dose. Others pointed out that concepts applicable in partial-body irradiation were not necessarily transferable to total-body irradiation. O'Foghludha indicated that it would not avoid the issue to give a complete description of the doses at different parts of the body. He said that the phantom studies of Hayes, Oddie, and Brucer (*9*) were as complete as one might wish, yet the information contained in the isodose plots was not readily usable for the purpose of relating biological response to radiation dose; for this, one needed a single dose value.

The ORAU speakers went on to describe how they converted the doses, as given by the participating institutions, to average total-body dose. They indicated that this study was still in progress and that data from only 21 of the 38

reporting institutions had been analyzed. Of the 757 treatments reviewed, exposures have been calculated for 724 and average doses have been calculated (or measured in phantoms) in 504. Table II gives the distribution of patients according to exposure and total-body average dose. About 5% of the patients could not be given any kind of dose estimate for lack of sufficient data.

Beck explained that the average total-body dose for ORAU patients was obtained by multiplying the patient's exposure by a conversion factor (Table III) derived from the phantom measurements of Hayes *et al.* (*9*). This factor is the ratio of the average number of rads per roentgen of exposure and is sensitive to patient size and weight. For the ^{60}Co opposing-field technique, the average dose changes more rapidly with patient weight than for the 8-source ^{137}Cs facility.

Average doses for the Cincinnati General Hospital patients were estimated by using the ORAU conversion factors for the temporary ^{60}Co unit in the third column, Table III. This was justifiable because the irradiation techniques at both institutions were almost identical (bilateral ^{60}Co radiation in both cases; treatment distances of 282 cm at Cincinnati, 275 to 285 cm at ORAU). Furthermore, a comparison of measured central-axis depth-dose data showed that the radiation distribution inside a phantom was the same at both facilities (Fig. 2). The data from Mary Imogene Bassett Hospital were treated in the same way although a comparison of central-axis depth-dose curves could not be made.

The City of Hope Hospital reported their doses as "average midplane, midbody dose" (*3*). This dose is the arithmetic mean of point values in the midcoronal plane of the trunk. For the NASA study, the reported values were converted to average total-body doses by means of the conversion factors of Table III. Justification for using the factors in Table III, which were determined for the 8-source ORAU irradiator, was the similarity of the ORAU and City of Hope facilities. A comparison of the radiation distribution measured in phantoms at ORAU and City of Hope showed that the dose at similar points was almost identical.

Whereas in gamma-irradiated patients dosimetry had been based on experimentally determined data, the same approach could not be followed for the far greater number of patients treated with X rays. The irradiation conditions varied so that phantom studies designed to reproduce all combinations of radiation energy, distance, and HVT would have been

impractical. Instead, Cloutier explained, average doses were calculated by means of Mayneord's equations (*12*, *13*, *14*), which give average dose as the product of the mean skin dose and certain tabulated factors. The skin dose usually had to be calculated from the midline air exposure; this was straightforward except for some uncertainty about the proper choice of backscatter factors.

Mayneord's calculations require a knowledge of the radiation quality and the trunk dimensions. In those cases where the HVT of the beam was not recorded, no estimate of average dose could be obtained; when the trunk dimensions were unknown, it was assumed that the correct AP trunk thickness was given by the expression (*15*):

$$\text{AP (cm)} = \sqrt{\frac{\text{weight (g)}}{\text{height (cm)}}}$$

It was also assumed that the lateral dimension was 1.5 times the AP thickness.

As a check on the validity of Mayneord's method of calculation, three phantoms were irradiated with 250-kV X rays (HVT 1.8 mm Cu) and average doses were measured with a ferrous sulfate dosimeter. The agreement between measured values and those obtained by Mayneord's method is good for the adolescent phantom, only fair for the adult, and poor for the child (Table IV). This may be a result of the failure of the theory when applied to conditions very different from those assumed in deriving it, incorrect choice of constants, or a combination of both factors.

The measured average total-body dose, for one roentgen exposure in air at the midbody position, is higher for this radiation quality than for a similar opposing-beam treatment using ^{60}Co radiation. The radiation distribution inside the phantom, however, is presumably less uniform, although this was not investigated.

[Excerpt continues on p. 17]

with 350 rads delivered nonuniformly. The equivalence arises because 350 rads delivered unilaterally spares the same number of stem cells as 270 rads delivered bilaterally.

CONCLUSIONS

How should Dose be Reported?

All participants agreed that specification of the radiation field alone was insufficient to describe the irradiation completely. For example, a statement of the exposure in roentgens, although forming an essential part of the record, is not enough. An attempt should always be made to specify the energy deposition or dose. If details of the method and results of dose measurements as well as the exposure are quoted, later recalculation is possible and intercomparison with the results of others is simplified.

In specifying the dose a choice must be made between the maximum, minimum, modal, integral, or average doses (*31*). The physical arguments for and against the various specifications have already been given. The choice depends to some extent on the response that is clinically interesting or important. Langham cited the possibility of erythema in an astronaut exposed to low-energy radiation. In this circumstance the skin dose is of critical importance. On the other hand if lethality is the response under study, the dose to the bone marrow is most important since the marrow appears to be the target organ, at least when the dose is of the same order of magnitude as the $ED_{50/60}$. In some situations, of course, the target organ is unknown as in the prodromal syndrome where the means by which anorexia, nausea, and vomiting are induced remain obscure. Since the onset of these symptoms is unlikely to be related to irradiation of the extremities, a specification of the average dose to the trunk - or possibly the upper abdomen alone - is of value. Where the physiologically important organ cannot be localized even to this degree of accuracy, the average dose to the whole body is the most appropriate value to quote.

The average dose has the advantage that it can be calculated with fair accuracy in most cases if the properties of the radiation field are known. Whether D_{av} is required for a single organ or for the entire body, its determination involves measurement or calculation of the integral dose Σ,

either explicity or conceptually. For this reason it may be advantageous to state D_{av} not in rads but in the dimensionally equivalent form "gram-rad per gram"; such a statement, though clumsy, draws attention to the way in which D_{av} was actually obtained.

The extremes between which values of the local dose vary should be reported as an indication of the degree of nonuniformity. If the frequency distribution about the mean were normal, the standard deviation could be used; but it is usually most appropriate to indicate the spread by quoting the highest and lowest doses in the region of interest.

National and international organizations have recommended standards for dose recording in portal therapy. Until similar standards are set up for total-body irradiation, it is suggested that:

1.) The characteristics of the radiation field used should be stated.

2.) The average dose D_{av} in the target organ and the method of calculation or measurement should be given. If the target organ is unknown, D_{av} for the entire body should be stated.

3.) The maximum and minimum doses in the region of interest or some other indication of the degree of nonuniformity should be reported.

Whatever method of dose specification is used, a single number is unlikely to provide a firm basis for the prediction of biological response. The more data one quotes, the more complete is the information, though the additional data may appear irrelevant or even confusing. Past experience proves that information once thought to be unimportant is later vital. Therefore, as much information as possible should be recorded to permit later evaluation in the light of new identification of target organs.

At the present time Mayneord's analytical technique and Snyder's computer study of individual photon histories offer powerful tools for the calculation of radiation dose. However, additional experimental corroboration of these theoretical methods is urgently needed for various phantoms and for a range of photon energies. The participants at this meeting expressed the hope that the next few years would see a rapid advance in the science of whole-body dosimetry.

REFERENCES

1. M. Brucer, A total-body irradiator, Int. J. Appl. Radiat. 10: 99-105, 1961.

2. A. C. Morris, Jr., Measurements in a total-body irradiation facility, Int. J. Appl. Radiat. 11: 108-113, 1961

3. M. L. Jacobs and L. Pape, Dosimetry for a total-body irradiation chamber, Radiology 77: 788-792, 1961.

4. J. B. Dealy, Jr., The theory and practice of total-body irradiation in the dawn on the homograft era, Radiology 75: 11-18, 1960.

5. E. D. Thomas, E. C. Herman, Jr., W. E. Greenough III, E. B. Hager, J. H. Cannon, O. D. Sahler, and J. W. Ferrebee, Irradiation and marrow infusion in leukemia, Arch. Intern. Med. 107: 829-845, 1961.

6. W. K. Sinclair and A. Cole, The technique and dosimetry for whole body x-irradiation of patients, School of Aviation Med USAF Randolph AFB, Texas Res. Report AF-SAM-57-70 March, 1957.

7. V. P. Collins and R. K. Loeffler, The therapeutic use of single doses of total body radiation, Amer. J. Roentgenol. 75: 542-547, 1956.

8. V. P. Collins, C. T. Teng, W. R. Karn, and W. D. West, A study of the effects of total and partial body radiation on iron metabolism and hematopoiesis, Progress Report for Period 1 March 1958 - 31 May 1958. U. S. Dept. of the Army Report No. AD-161956.

9. R. L. Hayes, T. H. Oddie, and M. Brucer, Dose comparison of two total-body irradiation facilities, Int. J. Appl. Radiat. 15: 313-318, 1964.

10 E. L. Saenger, Metabolic changes in humans following total-body irradiation. (Period covered: Nov. 1, 1961-Apr. 31, 1963) Univ. Cincinnati College of Medicine, Research Report DASA - 1422.

11 A. F. Holloway and R. J. Walton, The design of a whole body irradiation room, J. Can. Assoc. Radiol. 12: 138-142, 1961.

12. W. V. Mayneord and J. R. Clarkson, Energy absorption II Part I. Integral dose when the whole body is irradiated, Brit. J. Radiol. 17: 151-157, 1944.

13. W. V. Mayneord and J. R. Clarkson, Energy Absorption II Part II. Integral dose when the whole body is irradiated, Brit. J. Radiol. 17: 177-182, 1944.

14. W. V. Mayneord, Energy Absorption III, The mathematical theory of integral dose and its applications in practice, Brit. J. Radiol. 17: 359-367, 1944.

15. Y. Naversten, In discussion of E. Oberhausen, Liquid scintillation whole-body counters, In clinical uses of whole-body counting, Proceedings of a Panel, Vienna, 28 June - 2 July 1965, International Atomic Energy Agency, Vienna, 1966, p. 15.

16. National Bureau of Standards Handbook 85, Physical Aspects of Irradiation, Recommendations of the International Commission on Radiological Units and Measurements (ICRU) Report 10b 1962, Washington D. C., U. S. Government Printing Office, 1964, p. 4.

17. National Bureau of Standards Handbook 78, Report of the International Commission on Radiological Units and Measurements (ICRU) 1959, Washington D. C., U. S. Government Printing Office, 1961, p. 13.

18. F. Bush, The estimation of energy absorption during teleradium treatment, Brit. J. Radiol. 16: 109-112, 1943.

19. W. S. Snyder, The variation of dose in man from exposure to a point source of gamma rays. International Conf. on Radiol. Protection in Individual uses of Radioisotopes, Paris, December 13-15, 1965 Health Physics Annual Progress Report ORNL - 4168. [also to be published in the Proc.]

20. R. L. Hayes and M. Brucer, Compartmentalized phantoms for the standard man, adolescent and child, Int. J. Appl. Radiat. 9: 113-118, 1960.

21. W. E. Lay and L. C. Fisher, Riding comfort and cushions. Soc. Automotive Engrs. 47: 482-496, 1940. Quoted in NASA SP-3006 (1964), page 251.

22. A. R. Jones, Measurement of the dose absorbed in various organs as a function of the external gamma ray exposure, Atomic Energy of Canada Ltd. Report AECL - 2240, Oct. 1940.

23. W. K. Sinclair, Absorbed dose in biological specimens irradiated externally with cobalt-60 gamma radiation. Radiat. Res. 20: 288-297, 1963.

24. L. G. Grimmett, Discussion on the constitutional effects of radiation, with special reference to volume dose, Brit. J. Radiol. 15: 144, 1942.

25. H. H. Rossi, R. Leibowitz, and F. de Friess, Measurement of integral dose in unit density phantoms of uniform cross section, Radiology 72: 104-105, 1959.

26. C. Carlsson, Integral absorbed doses in roentgen diagnostics. A theoretical analysis and clinical application, Acta Univ. Lund., II #18, p. 1-9, 1964.

27. E. Zieler, Untersuchungen zur Bestimmung der Integraldosis in der Rontgendiagnostik, Fortschr. a. d. Geb. d. Rontgenstr. 94: 248-260, 1961.

28. L. V. King, Absorption problems in radioactivity, Phil. Mag. 23: 242-250, 1912.

29. W. V. Mayneord, Energy absorption IV, the mathematical theory of integral dose in radium therapy, Brit. J. Radiol. 18: 12-19, 1945.

30. F. O'Foghludha, Radiation reciprocity in a scattering medium: An experimental study, Phys. Med. Biol. 9: 155-165, 1964.

31. L. Sundbom and P. E. Asard, Tumor dose concept, Acta Radiol., Therapy, Physics, Biology, New Series 3 (2): 135-142, 1965.

TABLE I

JANUARY 1967 AUDIT OF RETROSPECTIVE AEC/NASA STUDY OF HUMAN TOTAL-BODY IRRADIATION

Hospital or Institution	Anticipated Treatments	Retrieved Treatments	Treatment Types <Day	>Day but <8 Days	>8 Days	No. of Treatments Reviewed for Dose Estimation
Albert Einstein Medical Center	1	1	1			1
Baylor University	113	111	67	15	29	74
Bowman Gray	7					
Burge Protestant Hospital	5	5	1	2	2	
Cincinnati General	32	32	29	1	2	30
City of Hope Medical Center	53	58	36	8	14	43
Charity Hospital	80	98	3	18	77	
Colorado General	1	1			1	
Ellis Fischel State Cancer Center	77	84	2	9	73	
Franklin Hospital	85	85			85	
Jefferson Medical College	10	11	11			4
Long Beach Community Hospital	1	1	1			1
Los Alamos Hospital	9	9	9			1
Mary Imogene Bassett	22	27	15	11	1	19
Massachusetts General (McGovern)	6	7	7			7
Massachusetts General (Robbins, L.)	200					
M. D. Anderson Hospital & Tumor Institute	293	292	286	1	5	287
Medical College of Virginia	5	5	5			5
New York Memorial (Craver--Heublein)	144	188		112	76	108
New York Memorial (Nickson)	46	48	35	6	7	23
Oak Ridge Associated Universities-ORINS	138	138	134	1	3	123
Penrose Cancer Clinic	54	68			68	
Peter Bent Brigham	10	11	2	8	1	10
Philadelphia Children's	3					
Providence Hospital	45	288	236	3	49	
Rhode Island Accident	1	1	1			
Temple University	26	29	15	5	9	7
Thomas M. Fitzgerald Mercy	4	4	4			4
U. S. Naval Hospital	11	11	7		4	7
U. of Calif. Medical School, S. F.	163					
University of Michigan	128	128			128	
University of Pennsylvania	10					
V. A. Hospital at Denver	12	25	2		23	
V. A. Hospital at Long Beach	10	2	2			2
V. A. Hospital at New Orleans	24	57	5	16	36	
V. A. Hospital at Wood, Wisconsin	1					
Winnipeg General	7					
White Memorial Medical Center	2	2	2			2
Totals 38 Institutions	1839	1814	904	216	648	757

TABLE II

DISTRIBUTION OF PATIENTS
ACCORDING TO EXPOSURE AND TOTAL-BODY AVERAGE DOSE

Exposure (R)	Number of Patients	Total-Body Average Dose (rads)	Number of Patients
0-25	155	0-25	149
26-50	152	26-50	108
51-75	51	51-75	90
76-100	127	76-100	19
101-125	47	101-125	17
126-150	37	126-150	36
151-200	60	151-200	19
201-250	16	201-250	26
251-300	22	251-300	4
301-400	16	301-400	15
401-500	11	401-500	7
501-700	13	501-700	7
701-900	5	701-900	2
901-1100	6	901-1100	3
1101-1300	3	1101-1300	2
1301-1600	3	1301-1600	0
	724		504

January, 1967

TABLE III

ORAU WEIGHT-CORRECTED
CONVERSION FACTORS

Patient's Weight (Pounds)	AVERAGE TOTAL-BODY RAD/R	
	^{137}Cs TBI Facility	Temporary ^{60}Co Unit
35-45	0.75	0.77
45-55	0.75	0.74
55-65	0.75	0.71
65-75	0.75	0.69
75-85	0.74	0.67
85-95	0.74	0.65
95-105	0.74	0.64
105-115	0.73	0.63
115-125	0.72	0.62
125-135	0.72	0.61
135-145	0.71	0.61
145-155	0.70	0.61
155-165	0.70	0.61
165-175	0.69	0.61
175-185	0.69	0.60
185-195	0.68	0.60
195-205	0.68	0.60

TABLE IV

COMPARISON OF MEASURED AND
CALCULATED AVERAGE DOSES

Phantom	Thickness	SSD	Average dose/R exposure		% Difference
			Measured	Calculated	
Adult	29 cm	285 cm	0.67	0.73	9
Adolescent	23 cm	200 cm	0.78	0.80	3
Child	16 cm	200 cm	0.79	0.93	18

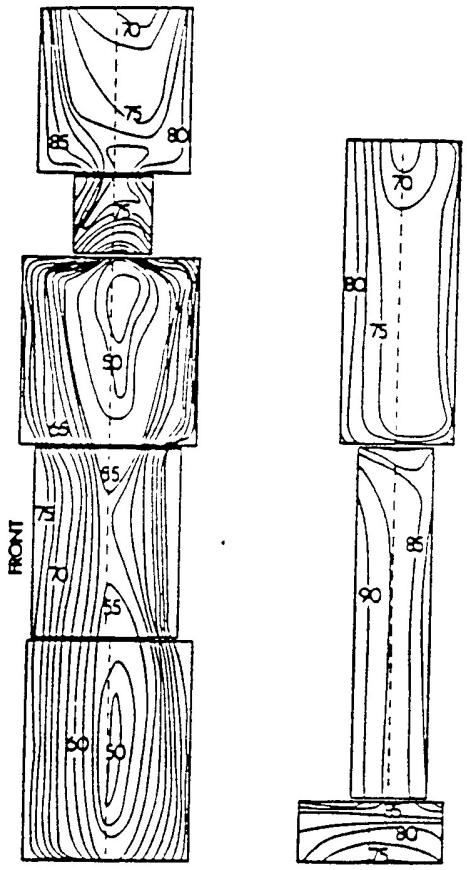

Figure 1. Isodose lines in an "adult" phantom, irradiated with eight converging ^{137}Cs radiation beams. ORAU total-body irradiation facility. Isodose lines normalized to 100-R exposure at the center of the phantom.

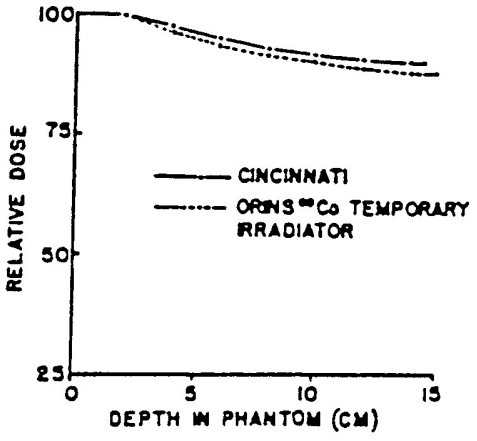

Figure 2. Central-axis depth-dose curves in the "trunk" of phantoms irradiated with opposing ^{60}Co radiation beams. Depth doses normalized to 100 at the phantom's surface.

Appendix I

WORK CONFERENCE

List of Participants
Program

WORK CONFERENCE

DOSIMETRY IN TOTAL BODY PHOTON IRRADIATION OF MAN

February 23-24, 1967

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RADIATION LABORATORY
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31 December 1946

Dr. Hamilton -
RC
report (146)

To: Colonel K. D. Nichols

From: Joseph G. Hamilton, M. D.

Subject: RADIOACTIVE WARFARE

The use of fission products as a military agent presents a number of very novel considerations which distinguish this potential weapon from chemical tools of war, such as mustard gas, lewisite, phosgene, et cetera. The major differences between chemical and radioactive poisons may be divided into the following principal categories. One; the quantity of radioactive poison required to produce lethal effects can be measured in the range of micrograms while in the case of chemical agents, there is usually required tens to hundreds of milligrams to produce comparable biological damage. Two; it is impossible to detect the presence of radioactive poisons without the aid of suitable electrical devices such as Geiger counters, ionization chambers, electroscopes, et cetera. In other words, the radiation from radioactive materials cannot be detected by touch, smell, taste, et cetera. Three; the biological damage produced by such radiations has a high degree of latency in that even with lethal dosages, the full effects may not appear for intervals extending from days to the order of several months. In addition, complete recovery from sub-lethal injury may not occur in a considerable portion of individuals exposed and this factor of chronic injury may be expected to occur in a much higher proportion of subjects than might be expected from sub-lethal chemical injuries from most, if not all, of the known war gases. Four; radioactive poisons may persist in an infected region for extremely long periods of time, if the material injected has a sufficiently long half-life. Five; removal of radioactive materials once they have become deposited on soils, buildings, roads, et cetera, will be in most instances so difficult that for all intents and purposes, decontamination may be considered an almost insurmountable problem.

The fission products can be employed either against personnel, both civilian and military, or they may be used to impair if not destroy the use of agricultural areas for the purpose of producing food crops. These materials can produce injury to man, as well as animals. Injury can arise from several different mechanisms, namely, inhalation, ingestion, and external irradiation. Following absorption into the body the majority of the longer-lived fission products, whose half-lives extend from the order of two weeks to many years, are accumulated and tenaciously retained in the skeleton. There, they produce internal irradiation of the very sensitive bone marrow and even rather trivial amounts can produce lethal effects. The inhalation of finely suspended particles such as dust or smoke, containing a mixture of the longer-lived fission products is attended by a

significant percentage of inhaled material being retained in the lungs for intervals extending to as long as a year. A variable but significant fraction of the fission products initially retained by the lungs following inhalation will be absorbed through the lung tissues into the blood stream and then be deposited within the skeleton. In general, the damage to the lungs will be greater than to the blood forming tissues within the bone marrow. However, it is perfectly feasible to prepare radioactive smoke of such a character so that the injury to the bone marrow will predominate over pulmonary damage. The oral ingestion of many of the fission products is followed by a rather trivial degree of absorption from the digestive tract. If an unseparated mixture of long-lived fission products is employed, less than from 3% to 10% will be absorbed through the digestive tract. Approximately half of the material so absorbed will become deposited within the skeleton. External irradiation arising from fission products spread over a large area, presents another important aspect of the problem of radioactive warfare. Inasmuch as both beta and gamma rays are emitted from the fission products mixture, superficial as well as penetrating damage may occur. In the main, the gamma rays will be the more ominous of the two radiations insofar as lethal injury to personnel is concerned. From 400 to 600 roentgens is believed to constitute an acute lethal dose of penetrating gamma rays for an adult human. Severe and slow healing lesions of the skin and subcutaneous tissues will occur following 3,000 to 6,000 roentgens of beta irradiation of an energy range from 250,000 to 2,000,000 volts. Due to the fact that beta rays are relatively easily absorbed, a considerable diminution of that effect will arise from absorption in clothing, shoes, et cetera.

The contamination of soils presents another aspect of the destructive potentialities of the fission products as a military agent. The accompanying report on the behavior of fission products and soils elucidates this issue to a considerable degree. Briefly, the situation is that most of the long-lived fission products, because of their chemical properties become extremely firmly fixed on to soil particles. Plants growing in such contaminated soils have the potentiality of accumulating to a very high degree, a considerable fraction of the fission products that are fixed upon the soil particles. Inasmuch as this accumulation by the plants occurs chiefly in the roots which are relatively sensitive to radiation, it can be readily appreciated that significant areas of ground may be made essentially sterile insofar as their agricultural use is concerned. In addition, there is a corollary problem which arises, namely, the assimulation of certain fission products, notably cesium and strontium in the leafy portions of plants. Conceivably, food crops growing in soils contaminated below the level required to kill plants could result in the poisoning of the plant products insofar as animal or human consumption is concerned.

The quantity of given fission product mixture that is required to produce damaging effects, whether it be in humans or plants, depends upon the age and composition of the fission product mixture employed. Obviously, there is almost an unlimited series of numbers which could

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be given for such amounts since there are not only many elements involved in the fission product series but also the half-lives of the individual elements produced in fission extend from seconds to centuries. However, as a practical consideration, the most effective group of fission product elements, as military agents, are those whose half-lives range from several weeks to the order of a year. This group of fission products will serve as the basis for the values subsequently given. More precisely, it will be for a mixture of fission products that exist in an irradiated natural mixture of uranium for a period of 100 days which is then allowed to cool for a period of 60 days before removal of the fission products as a group.

As a result of tracer studies done at Berkeley, and subsequent experiments including an investigation of radiation effects which were accomplished elsewhere on the Project, the following cursory picture has been compiled. The inhalation of 10 millicuries of the unseparated fission product mixture described above is estimated to be a minimum lethal dose for the average adult human. It is presumed that lethal injury will arise in the main through pulmonary damage rather than bone marrow destruction. The oral ingestion of at least 100 millicuries of such a mixture would be required to produce lethal injury which in this case would arise primarily from bone marrow damage produced from the strontium and barium absorbed from the digestive tract and subsequently deposited in the skeleton. An estimate of the amount of this fission product mixture required to produce external gamma ray injury can best be expressed in the following manner; 1 curie of radium gamma ray equivalent per square meter spread over a large plain area will produce at a level of 1 centimeter from the ground - 0.8 roentgens per minute, 10 centimeters from the ground - 0.6 roentgens per minute, and 100 centimeters from the ground - 0.4 roentgens per minute. Expressed in terms of roentgens per day, corresponding values are 115 roentgens, 86 roentgens, and 57 roentgens, respectively. In estimating these values, an average gamma ray energy of 0.7 Mev was assumed and absorption in the air as well as self absorption in the soil have been ignored. The corresponding amount of beta irradiation is very difficult to estimate in view of the variation produced by the different thickness of articles of clothing, et cetera. In general, however, it is likely that the gamma ray effects will predominate as the more destructive. Inasmuch as 100 r of total body radiation can be expected to produce, in a significant number of individuals, some degree of irreversible radiation damage, it would appear that a flux of gamma rays at this intensity would render such an area essentially uninhabitable. It should be kept in mind that the values given above for gamma radiation represent a hypothetical situation inasmuch as distribution will never be uniform and there will be other variations due to the presence of buildings, trees, and irregularities of terrain. A detailed discussion of the amounts of material required to produce crop damage is presented in the accompanying report. A more precise evaluation of the quantities involved for the sterilization of agricultural lands must await the accumulation of further scientific knowledge in this field of investigation.

In addition to the critical effect upon living plants follo[illegible] the contamination of large areas, there is a further consideration [illegible]

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presents a most ominous complication. Assuming a relatively uniform and widespread deposition of fission products over areas of many square miles, there will arise varying and unpredictable concentrations of this activity as a result of rain or melting snows. It must be realized that initially a large fraction of the deposited fission products will be on the surface of the soil, plants, buildings, roads, et cetera, as a thin film of dust. Rain or melting snows will wash a significant fraction of these materials away and they will be accumulated in the run-off water and may be carried considerable distances to another location. It is quite logical that a redistribution in a concentrated form would prove most disturbing, particularly from the point of view of gamma radiation if such removal and redistribution should occur in a thickly populated area.

The possible methods of distribution of fission products that are of military significance have been investigated only to a very limited degree and on an extremely small scale. Such methods were developed primarily at Berkeley for the purposes of studying the behavior of fission product aerosols following their inhalation by animals. Stable aerosols may be produced by depositing fission products upon a smoke producing agent, as for example, the zinc hexachlorethane-ammonium perchlorate mixture which has been used for many years for the purpose of obscuration. Such a type of preparation would appear well adapted for producing fission product aerosols to subject urban populations to fission product poisoning by inhalation. Other possibilities present themselves such as dispersal of a fine powder by means of a bursting charge, the reduction of the principal fission products to a metallic state and their subsequent combustion to form finely divided oxide smokes, the production of fine sprays of solutions of fission products, and the dispersion of a fission product mixture in the form of small particles of the size of the order of 0.1 millimeter in diameter. These are problems about which there are many individuals better qualified than I to present intelligent suggestions. It should be pointed out that in many instances, it is to be presumed that where aerosol concentrations of fission products can be created at sufficient levels to produce serious biological damage as a result of inhalation, there will occur the deposition of such suspensions upon the ground in sufficient quantities that will approach, if not exceed the radiation flux, that will result in severe external gamma ray damage to individuals so exposed.

There are known at present very few and relatively inadequate measures that can be employed to combat the problems arising from radioactive warfare. In the first place, the removal of long-lived fission products, once they have become either deposited within the lungs or absorbed in the body, has been unsuccessful. Absorption from the digestive tract following oral ingestion can be reduced significantly by increasing the calcium content of diet for several weeks before administration of the fission products. The administration of calcium or strontium at the time of absorption or subsequently, is not of significant value. The administration of strong cathartics at the time of oral ingestion would be of value to reduce the

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time interval when the unabsorbed fission products would remain within the digestive tract and hence reduce the degree of local radiation of these organs. However, absorption of fission products from the digestive tract is not significantly reduced by the use of cathartics. Obviously, it is not practical to adequately protect individuals from external gamma radiation if they are to move about in areas which have been heavily contaminated. The type of lead armour that would be required would weigh many tons. In addition, it should be pointed out that there is no satisfactory method for combating the effects of radiation once the individual has been so exposed. In brief, there is no satisfactory method of reducing the effects on personnel from fission products either following introduction of these agents into the body or after damaging external body exposure has been received.

The recent and illuminating experiences from Operation Crossroads emphasizes the difficulties that will be encountered when external objects become contaminated with fission products. It is essentially impossible to leach them from soils and the difficulties that will present themselves for the decontamination of buildings, roads, and other man-made structures may be expected to be almost equally insurmountable. In other words, once these agents are deposited, the treatment of both animate and inanimate objects that have become infected with radioactivity would appear to be an almost hopeless task in light of our present knowledge. The previous preparation of areas that may be expected to be so exposed offers only limited encouragement.

The most significant remedial measures that may be taken following the deposition of fission products will fall into two major categories. First, the rapid evacuation of personnel in such areas as may be infected, and a prompt survey of all such individuals so that those who have received sufficient material to expect serious damage may be hospitalized for whatever palliative measures may be available to reduce their distress. At the same time, such a weeding out process makes it possible to release individuals who are relatively free from radioactive contamination for whatever activities that may be needed under such circumstances. It is possible to organize a very rapid and relatively precise means for making the type of discrimination noted above if proper arrangements have been made beforehand. The second phase of this problem is, of course, the prompt monitoring of infected areas so that the degree of contamination and danger can be properly determined. The detection of damage to individuals from external gamma ray irradiation is less satisfactory. This is due to the fact that frequently the amount of irradiation required to produce immediate reactions of radiation sickness such as nausea, vomiting, et cetera, is not far from the lethal dose. The change in number and distribution of the leukocytes of the circulating blood is relatively sensitive to amounts of radiation in the range of 50 to 200 roentgens. However, due to the fact that the procedure of taking a blood count requires of the order of thirty minutes, it might be difficult to adequately examine large numbers of individuals within a short space of time.

The possible types of application of radioactive agents as military weapons can be initially divided into two major classifications;

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strategic and tactical. One of the principal strategic uses of fission products will probably be against the civilian population of large cities. It can be well imagined the degree of consternation, as well as fear and apprehension, that such an agent would produce upon a large urban population after its initial use. Apart from the effect upon the morale of the populace, there is of course, the possibility of rendering large areas within the city uninhabitable due to the prolonged gamma radiation of such contaminated areas. While it is entirely likely that the source of fear induced by such a weapon would be diminished as the population became better informed as to the nature and degree of hazard to be expected, the fact that large sections of cities would be rendered untenable would seriously dislocate the normal functioning of the nation as a whole were many cities to be involved simultaneously. Contamination of reservoirs does not appear to be a very effective use of fission products due to the fact that the majority of them would very quickly attach themselves to the concrete or earth containing the water and those that did not remain behind would tend to be caught in the water system with the result that little if any active material would actually reach the individuals dependent upon the water supply. It is possible, of course, that contamination of a very small reservoir by a large amount of active material might conceivably produce some effective contamination of the water, but even here, I do not believe it likely that the effectiveness of such a procedure would warrant the use of the large amount of material required. It would appear that fission products might be very effective for the denial of access to small key areas, notably railroads, shipyards, docks, highly concentrated large industrial establishments, as for example steel mills, power plants, factories producing essential commodities, et. cetera. The advantage, of course, of this type of interruption of function is that the regions so treated are not physically destroyed and if the appropriate fission product mixture is employed, the interval during which such areas are rendered inaccessible can be pretty much selected at will.

Possible tactical applications that are fairly obvious are the denial of certain areas to troops, notably beach heads, narrow mountain passes, canals, et cetera. The direct use of fission products either against massed troops or against personnel in trench fortifications, not readily neutralized by more conventional agents, might be quite effective. The possibility also presents itself of the contamination of military materiel of various types, as for example, aircraft, quartermaster stores, ammunition dumps, et cetera. It is entirely possible that the use of fission products might be effectively extended against naval vessels either by shelling, using missiles containing fission products, or by spraying the material over the entire ship.

It is extremely difficult for me to make intelligent evaluations of the relative importance of different strategic and tactical uses of radioactive agents since I am quite unfamiliar with military science. Before leaving this phase of the application of radioactivity to warfare, it is pertinent to point out that the amount of fission products produced in creation of sufficient plutonium for a bomb would be adequate to render uninhabitable for a period of weeks to months an area that is comparable to

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that destroyed by the explosion of a single bomb. When it is considered that is is possible that within the next decade there will be produced plutonium in amounts which may approach an annual level in the range of tens of tons, it becomes apparent a nation producing such material at this level would possess the potentiality of rendering tens of thousands of square miles completely uninhabitable even for intervals of the order of a few days.

I strongly feel that the best protection that this nation can secure against the possibilities of radioactive agents being employed as a military tool by some foreign power is a thorough evaluation and understanding of the full potentiality of such an agent. Even if it were possible to predict the evil consequences that will result from the use of such an unpleasant military implement, such conclusions that could be made would be inadequate. In other words, I believe that it is necessary for the adequate defenses of this nation that an active and comprehensive examination of the entire problem be made by the armed services. Such a program, I feel should be carried out by the Chemical Warfare Service with the collaboration of other interested branches of the army and the navy. Inasmuch as it is apparent that such studies must be made by means of large scale experimentation, as well as laboratory research, it will be essential that there be made available in some isolated region an extensive proving ground. Here a large variety of field trials could be conducted, the nature of which are suggested in earlier discussions in this report.

To me, it would appear that the Chemical Warfare Service, in view of its long-standing experience in the use of other chemical and physical agents of warfare, would be best adapted to undertake and supervise such a program. In addition, it would appear highly desirable to appoint a civilian advisory committee composed of a group of chemists, physicists, and men trained in the medical and biological sciences. This group of civilian scientists, which would presumably be drawn from qualified individuals who have had extensive experience in the different aspects of the recent developments in nuclear energy, would serve to assist and advise the armed forces whenever such help would be needed. I believe that it would be inappropriate as well as difficult to seek the assistance of universities for direct research aid on most of the problems of investigation that the program indicated above would require. However, the fundamental knowledge in the fields of chemistry, physics, and medicine that is in the hands of the civilian scientists should be drawn upon freely.

JOSEPH G. HAMILTON, M. D.

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